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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

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Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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Measurement Techniques

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MAIN TRENDS IN THE DEVELOPMENT OF MEASUREMENT TECHNIQUES

V. O. Arutyunov

Translated from Izmeritel'naya Tekhnika, No. 5,
pp. 1-5, May, 1961

Soviet science and technology astound the world by their outstanding achievements and the exceptionally high rate of their development. Almost every year new achievements are announced in nuclear physics, chemistry, rocket technology, cosmic navigation and other spheres.

On April 12, 1961 the whole world was amazed by Yuri Gagarin's first flight into outer space. This outstanding feat of a Soviet man and an event of great scientific importance was the result of tremendous work in the sphere of science and engineering of Soviet scientists, designers and workmen, based on numerous theoretical investigations, precisely and carefully prepared experiments, on an accurate implementation of many new design features.

The flight into outer space could be transformed from a dream into reality only because the achievements of science and technology, the skill of Soviet engineers and workers, were reinforced by the heroism of an ordinary Soviet man, a heroism whose roots stem from the Great October Socialist Revolution and are fed by the great ideals of communism.

The present achievements and unprecedented rates of development of Soviet science and technology have but one explanation; namely, that only a socialist state system could have put at the disposal of our science all the required means and possibilities for solving the most varied and complex problems. In this extensive scientific arsenal one of the foremost places is occupied by the combination of all the measuring devices and instruments, without which not a single scientific experiment or investigation or industrial process can be carried out.

The high level of development of measurement techniques ahead of other branches is a prerequisite for the successful advancement of science and technology in all the branches of our national economy. The further and deeper development of scientific research and new technology present increasingly more stringent requirements with respect to accuracy and versatility of measurement methods and equipment. That is why research of measurement techniques and the design of new, improved and more precise measuring equipment should never lag behing the general development of science and industry, but on the contrary should always lead them. It is therefore necessary to establish what scientific and technological problems are facing modern measurement techniques and what means should be used for solving them.

Problem of diversity. One of the pressing problems is the development of new methods and means for measuring quantities which never had to be measured before. Thus, in modern chemical production and control of technological processes it is necessary to evaluate physicochemical quantities for which no measurement methods or equipment have as yet been developed. Means are required for measuring the thermal efficiency of gas and liquid fuel or fuel mixtures; it is necessary to develop contactless methods of measuring the characteristics of the air immediately above the ground, and the composition and quality of soil are also pressing problems. Objective and reliable means for evaluating the quality of agricultural produce, particularly the measurement of the moisture content of grain, are required. Modern building materials should be tested for homogeneity, plasticity, solidity, heat and sound conductivity, etc. The textile industry requires objective means for checking the quality and properties of various fabrics. The food industry requires measuring equipment for evaluating the moisture, composition, taste properties of semifinished articles and means for their continuous inspection. Numerous and diverse measuring instruments are urgently required for an objective diagnoisis, and evaluation of the properties of drugs, for precise dosage of medicines, especially of various types of radiations. The most diverse and unique measuring devices are required for modern science.

The requirement for measuring new physical quantities obviously necessitates the establishment and reproduction of new measuring units, without which, of course, no measurements are possible. This purely metrological problem must be solved before any development of the corresponding measurement equipment.

It will be seen from the above that the problem of establishing new means of measurement, the problem of diversity, is one of the most important tasks of the measurement technology. Wide scientific research and experimental development work should be directed toward the solution of this problem by using the unique possibilities presented by modern science, especially nuclear physics, and in particular radioactive isotopes, whose application has already produced many brilliant results. Proton resonance has also been used in a most versatile manner for measuring diverse properties, for instance, the moisture content of grain. Many other possibilities presented by the achievements in nuclear physics and other branches of science could also be pointed out.

Especially wide prospects are opened up by the use of computer and pulse techniques. Modern production processes consist of a very complex combination of many physical, chemical, thermal, mechanical and other processes, whose combined effect must be considered at any given moment, without which it is often impossible to provide the required technology of production. Computer techniques in combination with atuomation make it possible not only rapidly and simultaneously to account for all the factors characterizing the process, but also to make all the necessary calculations and send the final signal for a reliable control of the process. Complex measuring devices should, therefore, be developed with the application of the required computing elements which would provide the measurements results rapidly and accurately. Obviously, such devices should be developed on the basis of an appropriate scientific theory. The establishment of such a theory is one of the most important problems of metrology.

The problem of accuracy is also very important, since the finding and application of new, more accurate measuring devices are decisive for the development of modern, advanced branches of science and technology which are often held back precisely for the lack of such equipment. Only a few years ago it was possible to be content with a relatively low accuracy of measurements; the accuracy required at present approaches that of the best reference measurements and sometimes even exceeds it. Thus, in practice, it is often required to measure pressure with an error not exceeding 0.001%, voltage and angular velocity with the same or even a smaller error, the frequency of electromagnetic oscillations with an error not exceeding 10^{-8}–10^{-9}%, linear and angular dimensions with an error not exceeding 10^{-4}%.

Hence, the finding of new methods for providing a measurement accuracy several orders higher than the present one, and, moreover, under practical measuring conditions and not those provided in metrological establishments, is a problem of paramount importance.

One of the means for achieving high precision is the application of discrete measuring methods by using compute techniques. Many measured quantities are by their very physical nature discrete phenomena. Thus, electrical current is determined by the number of electrons passing per unit of time in a given cross section; pressure can be evaluated by the number of collisions of molecules; the purity of a material by the ratio of polluting atoms to the atoms of the basic substance, etc. If it were possible by means of modern computers to count the number of electrons passing through a given cross section even in batches of 10^9 electrons, the error in measuring 1 amp would then be reduced to 10^{-10}, which is several orders better than the present accuracy. Obviously, in such measurements it is necessary to provide a high stability for all the circuit elements and to eliminate the possible alteration of any of their properties under the effect of external factors, or to provide special means for compensating these variations, for instance, by self-adjustment techniques.

The requirement for more accurate laboratory and commercial measurements makes it necessary to establish more accurate standards. In fact, whatever methods are used for raising the accuracy of measurements, however well the new instruments are designed, they must all be calibrated, and for this purpose standards and reference devices are necessary for reproducing the measuring units with even greater accuracy. Hence, new and vast metrological research is required for providing a new system of more accurate standards and reference instruments than those used at present.

The increased accuracy in measuring physical constants provides a new possibility of transferring from artificial to natural standards. At the present time two of the four basic standards, namely, the meter and the second, are natural and the other two, the kilogram and the ampere, are artificial. Higher precision in measuring such constants as the gyromagnetic ratio and the acceleration due to gravity would also provide natural standards for the mass and the current on the basis of the above constants. In fact, the proton resonance phenomenon makes it possible to determine in

a reference coil, which provides a field strength H, the current I flowing through it by means of the gyromagnetic ratio and the well-known relation of $\omega = \gamma H$, where ω is the proton resonance frequency. Then, by using current balances for which the expression:

$$mg = I^2 \frac{dM}{dx},$$

holds, it is possible to determine the value of mass m if the acceleration g due to gravity is known and the mutual inductance M of the balance coil is determined from its dimensions and the number of turns. Obviously, in order to obtain the required accuracy in determining the current and mass, it is necessary to know the value of the gyromagnetic ratio and the acceleration due to gravity at least with an error not exceeding $10^{-6}-10^{-7}$.

Problem of the measuring range. Many modern scientific investigations require the measurement of very small as well as very large values of different variables. For instance, it is necessary to measure very small electrical currents (biological, ionization currents) of the order of 10^{-5} amp and smaller, radio-astronomical signals whose power amounts to $10^{-5}-10^{-18}$ w, pressures of $10^{-11}-10^{-12}$ mm Hg and at the same time pressures of several tens of thousands of atmospheres; it is necessary to measure temperatures of several tens of thousands of degrees and higher, as well as temperatures approaching absolute zero. Hence, one of the important tendencies of modern measurement techniques consists of extending the measurement range, i.e., developing on the one hand supersensitive measurements, and on the other methods and equipment for measuring exceedingly high values of variables.

Here computing technique methods are also very promising. Thus, if the measurement of current is reduced to counting electrons, the minimum measuring limit can be made considerably smaller than 10^{-15} amp. Similiar results can be obtained for other quantities if appropriate primary transducers are developed.

Similar satisfactory results may be obtained by developing various amplifying devices especially high and stable gain are required. The advances of modern electronic technology provide great possibilities in this respect, and its application is, therefore, one of the most rewarding trends in the activity of measurement laboratories.

The measurement of very large values is related on the one hand with the creation of special transforming (or converting) devices, and on the other, with the development of special means and methods for direct measurements. An example of transformation methods is the use of filters in optical pyrometry, attenuators in radio measurement techniques, as well as shunts and multiplying resistors in the technique of electrical measurements. However, it is possible by the already mentioned proton resonance to measure large currents without shunts, which is especially valuable in cases when transforming devices cannot be used. It is therefore necessary to develop measuring means especially suitable for determining extra-high values of different variables.

The problem of dynamic measurements. Instruments and devices for measuring rapidly changing quantities, i.e., for so-called dynamic measurements, are especially valuable for the development of many branches of science. In fact, the development of pulse techniques which involve single and periodic extremely short pulses, often of very great power, makes it necessary to search for means which would provide a sufficiently accurate evaluation of such pulse characteristics. Many phenomena due to the vibration of all kinds of machinery and constructions, both stationary and mobile, involve the measurement of oscillation parameters at most diverse frequencies. The study of such phenomena is, therefore, related to the measurement of variable quantities. In this respect measurement technology has made considerable strides. However, the production of more precise, and especially higher speed equipment for dynamic measurements is one of the most pressing problems.

This sphere of measurements is especially in need of reference equipment suitable for checking and calibrating measuring devices directly in dynamic conditions. As an example we can cite vibrometry with its numerous instruments and transducers for measuring the amplitude of vibrations, pulse acceleration and other parameters, whose calibration and accuracy checking are based on tests in a static condition, although it is known that the transition from static to dynamic conditions produces considerable additional errors.

The problem of special conditions. Modern conditions for conducting scientific and technical investigations involve a large number of various distorting factors; for instance, there exist at present many installations producing magnetic fields of various frequencies and intensities, which distort to a great extent measurement results. Owing to the existence of a large number of radio transmitting stations there is no spot on earth without the presence to a varying degree of radio waves, which produce considerable interference in electronic measuring equipment. Powerful and variable means of transportation as well as numerous machines and mechanisms produce vibrations and shaking

of buildings, which cannot be tolerated in any precision measurements. Moreover, the very nature of the investigated process or phenomenon makes it necessary to conduct measurements under the combined effect of various factors, such as high rarefraction and a very low or very high temperature, a simultaneous effect of vibrations and temperature or humidity, or of temperature and high pressure. In practice we encounter the most varied combinations of such factors.

All these special conditions naturally require special measuring devices. It is necessary, in the first place, to develop highly selective instruments and devices, and in the second place, to find the most effective protection against various interfering factors. If one also takes into account that certain modern physical phenomena (ultrashort waves, ionizing radiations) may affect the health of people, it becomes clear how important it is on the one hand to provide effective protection, and on the other means for evaluating the degree to which these phenomena affect people and to control these phenomena. Under these conditions it is especially important to establish scientifically valid standards for the protection of the personnel, which can only be obtained on the basis of carefully conducted measurements, and these in turn require appropriate measuring devices.

The problem of operational inspection in production. The complexity of modern technological processes, the necessity of maintaining with utmost accuracy the set conditions, and the wide application of automation require the production of control and measuring instruments especially suited for various specific production conditions. Measuring instruments and equipment designed for general commercial application will meet to a decreasing degree these special conditions. A visual readout of measurements can no longer be used in automatic production. Measuring devices must form an organic part of the automatic equipment, and hence should be especially adapted for a given technological process.

Measurement technology should provide modern production with all the means of operational inspection at all the manufacturing stages, from raw materials and semifinished articles to the final production testing. The technical progress of our industry depends to a great extent on the successful solution of this problem. Experience has shown that the quality, efficiency and economy of production, and the operational reliability of the products depend on the degree to which specially designed control and measuring devices are used in the manufacturing process. These devices must be operational, i.e., they should provide according to the measurement results the required adjustment of the technological process. Moreover, this problem is complicated by the fact that the majority of technological processes cannot be evaluated by a single parameter, but require several for that purpose. Hence, the control apparatus must provide the simultaneous measurement of these parameters, determine the resulting criteria of the technological process, and send a command signal for maintaining the controlled process in the required limits. Here an important part is played by data-collecting systems which "scan" with sufficient speed all the measuring points and provide the required final result.

The great variety of production methods and objects for monitoring requires a similiar variety of control and measuring devices. However, despite this fact it is possible and necessary to aim at a normalization and standardization of at least the basic elements and units instead of the devices as a whole. Thus, the normalization of primary transducers would make it possible to cover by a relatively small number of different types of transducers a large number of measured objects, by using the same actuating part in the measuring devices. Hence, one of the important trends in the development of operational production control should be the designing of unit-type systems consisting of a combination of standard measuring units which could provide the required variety of controls for different types of plants. At the same time, considerable attention should be paid to miniaturizing the measuring equipment.

The measurement techniques which will eventually solve the question of operational control under production conditions are only beginning to develop, but they will have to solve many problems whose value for modern production cannot be overestimated.

The problem of reliability. Whatever the purpose for which the measuring apparatus is intended, whether it is scientific research or industrial control, it must always be reliable. The concept of reliability also applies to any machine or mechanism; but in its application to measuring apparatus this concept has a special meaning, consisting in the fact that the measuring equipment must not only have a long life, be sturdy and resist external interference, but it must also provide completely reliable measurement results. In other words, the set tolerances must not change over a long enough time so as not to affect the reliability of measurement results.

Reliability in the general meaning of the word is determined by the quality of raw materials and the manufacture of any machine, whereas the reliability of measuring equipment is also affected by the measuring methods. The

latter should, therefore, be selected on the basis of the required degree of reliability according to the given measuring conditions.

Modern measuring equipment in the majority of cases consists of a complex combination of various elements, such as mechanical, electrical, optical, electronic, chemical and others. The requirements set for these elements in measurement techniques differ considerably from those prevailing in their direct application. Thus, the spread of electron tube characteristics permissible in receivers is completely inadmissible when the same tubes are used in measuring devices. The same applies to other elements. Hence, the provision of high reliability in the operation of measuring devices becomes an especially difficult task. That is why the production of components especially designed for measuring equipment, and possessing the required stable characteristics, is one of the decisive conditions not only for improving the reliability of the measuring equipment, but also for the further development of measurement techniques. The same range of problems includes the development of special alloys and materials with distinct physical properties, as well as the production of extra-pure solid, liquid and gas substances. Without this many pressing problems of measurement technology cannot be solved.

SUMMARY

We have only dwelt on the most important decisive trends of development in measurement techniques. The above by no means covers all the problems and tasks involved, but is it quite sufficient to convince one of the necessity for a radical expansion of scientific research in measurement technology, the extension of the number of institutes, experimental-design bureaus and specialized plants for the designing and production of precision and special measuring equipment. A general scientific and technical development program for Soviet measurement technology should be worked out. The degisning and production of the measuring equipment urgently required by our science and industry necessitates the establishment of a system which would provide a development of our measurement technology in advance of other industries.

INTERFEROMETER METHOD OF DETERMINING THE PARALLELISM OF LARGE BLOCK GAUGES

V. P. Koronkevich and V. P. Golubkova

Translated from Izmeritel'naya Tekhnika, No. 5
pp. 5-7, May, 1961

Recently several new interferometer instruments have been produced for checking the parallelism of block gauges [1,2,3,4].

Below we describe a method developed by the NGIMIP (Novosibirsk State Institute of Measures and Measuring Instruments) on the basis of the work described in [5] for checking the parallelism of block gauges 1000 mm long. In applying this method we used A. I. Kartashev's interferometer [5].

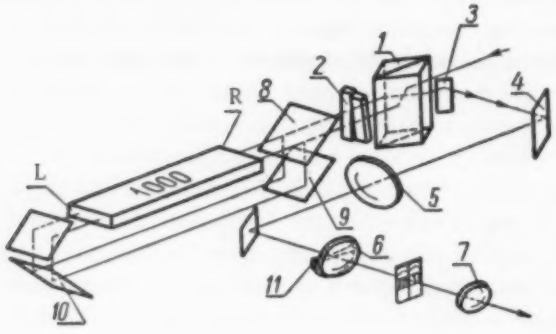

Fig. 1.

Figure 1 shows a simplified optical schematic of this instrument for measuring the parallelism of the faces at the ends of the long gauge. The rays of white light are transmitted from the input collimator (not shown on the drawing) to the double dividing prism 1. The coherent light beams on leaving the prism pass through Jamin's compensating plates 2 and fall on the right measuring surface R of the tested gauge. On reflection from the gauge the beams return to the prism and are reflected by the mirror unit 3 and 4 to the observation system consisting of collimator 5 and telescope 6 and 7. If the right-hand face of the gauge is at a small angle to the normal of the incident beam, interference fringes of equal thickness due to that face will appear in the field of vision of the optical system. In order to observe the interference pattern from the left-hand face L of the gauge, the device is provided with a light-dividing plate 8, mirror 9 and a mirror unit 10. The part of the rays reflected from plate 8 and mirrors 9 and 10 fall on the left-hand measuring face of the gauge and on reflection return over a path parallel to their original direction.

In order to separate the interference patterns obtained from the left-hand and right-hand measuring faces, a negative lens 11 is included in the interferometer objective. The action of this lens is twofold. In the first place, it divides the interference patterns, for which purpose it is placed slightly off-center with respect to the main optical system. In the second place, it brings to coincidence the interference fringe localizing plane of the left- and right-hand side measuring faces.

The light which does not fall on faces L and R is reflected from the mirror unit 10 and produces an interference pattern which fills the background between the images of the block gauge. If the edge of the mirror unit 10 is perpendicular to the dividing plane of prism 1 and the planes of mirrors 8 and 9 are parallel, the background fringes become indefinitely wide. The direction and order of the background interference fringes, when they have a finite width, depend on the original adjustment of the double prism 1 and the position of the compensator plates 2.

Three interference patterns L, R and B (Fig. 2) can be observed in the instrument's field of vision. The direction and position of the black achromatic fringe in pattern R measure the angle between the right-hand measuring face of the gauge and the wave-front, leaving the double prism 1. The direction and position of the achromatic fringe in pattern L measure the angle between the left-hand measuring face of the gauge and the wave-front leaving the mirror unit 10. The position of the black achromatic fringes is adjusted by turning the gauge, and their displacement along the field by rotating the compensator. The background fringes determine the angle between the beams incident to and reflected from the mirror unit 10 (Fig. 1).

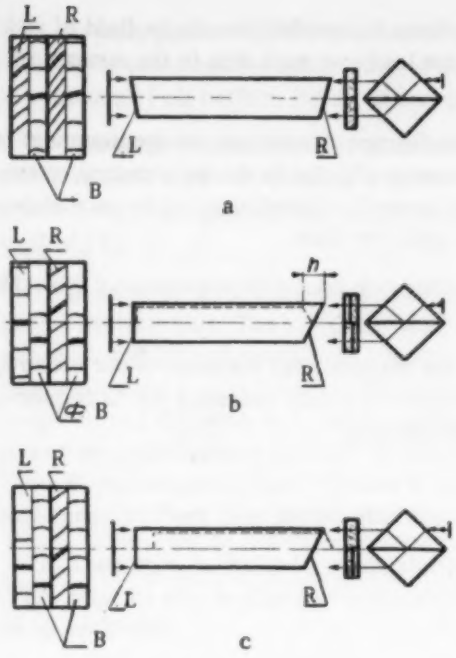

Fig. 2.

If the gauge measuring surfaces are parallel, the position of interference fringes in pattern L is similar to that in pattern R. If faces L and R are inclined with respect to each other, the black achromatic fringes will be in different positions of the interference field. Their displacement with respect to the corresponding points in the fields is a measure of the lack of parallelism.

One of the advantages of this method consists in the fact that the lack of parallelism with respect to the short side of the face does not produce either a displacement or a slanting of the fringes when the gauge is placed in the position shown in Fig. 1. This circumstance is explained by the fact that the rotation of the gauge measuring surface about its axis perpendicular to the dividing plane of the double prism will affect equally both pairs of corresponding rays which form the interference pattern.

In order to measure the deviation from parallelism with respect to the short side of the face it is necessary to turn the gauge through 90°. The field of vision obtained in measuring the parallelism with respect to the short side of the gauge face is shown in Fig. 2a, b, c.

There are several methods of determining parallelism. The simplest in our opinion, consists of the following:

1) The position of the gauge is adjusted by tipping the table in such a manner that the black achromatic fringe in pattern L becomes parallel to the background fringes. By rotating the compensator the black fringe is then made to coincide with the cross hairs and the first reading is taken (Fig. 2b);

2) The black achromatic fringe in pattern R is made to coincide with the image of the gauge side by turning the compensator (Fig. 2c) and then the second reading is taken.

In Fig. 2b and c the mirror image of one half of the gauge is shown by a dotted line. The displacement of the achromatic fringe to the edge of the gauge makes it possible to determine segment h, which amounts to twice the deviation from parallelism in that direction.

Owing to imperfections in the adjustment of the optical system a more precise method of determining parallelism between the L and R faces consists in taking the measurements in two positions of the gauge which differ from each other by 180°. If the background interference fringes are constant, the instrument errors for these two positions are the same and value of the inclination between faces L and R only changes in sign. Hence, the algebraic difference of the two measurements amounts to twice the value of the deviation from parallelism.

In order to test the above method of measurements the instrument was used for measuring several block gauges and the results thus obtained were compared with absolute measurements made by means of a Kester interferometer. It is true that such measurements could only be made for gauges 150 mm long. However, the measurement results did not differ by more than 0.02 μ.

The determination of parallelism in block gauges from 100 to 1000 mm long shows that the error of this method does not exceed 0.02-0.05μ.

The above method proved to be particularly useful in checking gauges under production conditions, since determining the difference in the length of the gauge along one of its sides only requires a few minutes. A constant temperature need not be observed, since the extension of the gauge with temperature does not affect the value of parallelism. The testing of the parallelism of gauges has shown that measurements of deviations up to 1.5μ are still possible. If the difference in the length of the gauge along one side exceeds 1.5μ it is only possible to determine the direction of the deviation and, hence, to inform the manufacturer of the direction in which the gauge should be rectified.

SUMMARY

1. Measurements are made according to this method without lapping the block gauges to flat plates.

2. The checking of parallelism does not require the use of a reference gauge.

3. The observation of the interference patterns from both measuring faces is provided in a single field of vision, and the variation in the length of gauges between 100 and 1000 mm does not lead to a reduction in the contrast of interference fringes.

4. The placing of the gauge on the instrument, adjustment of the interference pattern and the measurement itself require a minimum of time, since inclinations of the gauge in a plane perpendicular to the measurement plane do not produce differences in the length of the interfering beam paths, and hence the initial bringing to coincidence of the images of the two halves of the measured surface can be adjusted roughly by them.

5. The errors in determining the parallelism of block gauges 100 to 1000 mm long does not exceed 0.05μ. The maximum measurable lack of parallelism amounts to 1.5μ.

At present interferometers of the A. I. Kartashev system exist in all the metrological institutes of our country. The application of the above method does not therefore present any difficulties. It is only necessary for its implementation to make special stands for placing the gauge on one of the instrument carriages.

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OPERATION CONTROL ERRORS IN OBTAINING ACCURATE COUPLINGS

A. V. Vysotskii

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pp. 7-8, May, 1961

With the development of serial and mass production individual fitting operation have been replaced by separate and independent machining of the coupling details with set tolerances which provide the required type of coupling.

When the coupling must be accurate, i.e., when the gap or clearance tolerances are small, of the order of 1-6μ, requirements of complete interchangeability become uneconomical.

In such cases it is necessary to revert to individual fitting or introduce an incomplete (limited) interchangeability.

Individual fitting, which greatly raises the cost of production, is only applicable to the production of single articles. Moreover, lapping normally distorts the geometrical form of details, which deteriorates the quality of their coupling.

Incomplete interchangeability consists in machining the paired details with economically advantageous, relatively large tolerances, and then sorting them into groups whose tolerances provide complete interchangeability within each group. This method is applicable in large-scale mass-production, since a large number of details is required in order to provide the necessary pairing on assembly. In this case th shaft and the hole are usually tested by means of different measuring methods which makes the actual coupling worse than the calculated one, owing to a difference in the size and direction by which their actual and certified dimensions do not coincide.

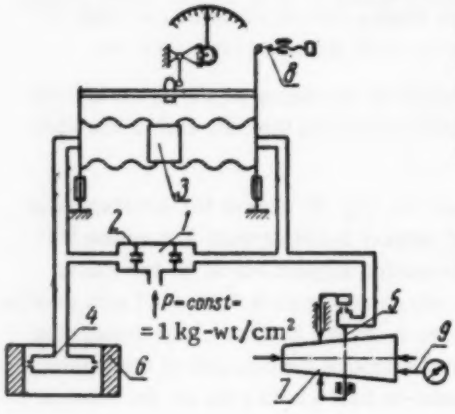
In mass-production, which forms a relatively large part of our engineering industry, the requirement for precise coupling is sufficiently large (fitting of accurate rolling bearings on the shaft and in the casing, the fitting of pistons to cylinders of air buffers, fitting of heating apparatus components, etc.).

The most rational method in such cases consists in producing the paired details with controlled machining in such a manner that the controlling device automatically sets the dimensions of the machined detail to those with which it has to be paired. This is attained in the simplest and sufficiently reliable manner by a pneumatic measuring method [1].

In order to investigate the possibilities of this method the Bureau of Interchangeability has conducted laboratory and production tests. The attached figure shows a schematic of an installation for determining the maximum error and the instability of readings in a static condition. The air is fed from the pressure stabilizer to distributer 1 with an input nozzle 2, and then to a differential bellows transducer 3. One branch of the system is connected to an internal gauge 4, and the other to a caliper gauge 5. During testing several rings 6 with a difference in diameters of 2μ were placed over the internal gauge. The caliper gauge was placed over the maximum diameter of a tapered shaft 7. Shaft 7 was displaced axially until contact 8 was closed. The position of shaft 7 at that instant was measured on the indicating gauge 9. Tests have shown that the maximum error does not exceed 0.5μ.

Tests were made under production conditions on a type 310P cylinder-and-cone grinding machine, with certified rings 14 mm in diameter and deviations of 30μ. A batch of shafts was ground for each ring and then measured on an optimeter.

Tests have shown that the dispersion in the value of gaps is within the limits of ±1.5μ.



With larger nominal coupling dimensions the stability of temperature of the machined detail, the finished detail to which it is paired, and of the measuring instrument becomes important. The best solution of this problem would consist in placing the machine in thermostatically controlled premises, stabilizing the temperature of the cooling lubricant liquid and of the oil hydraulic system of the machine.

In machining large size details it will, probably, also be necessary to compensate automatically the temperature difference between the measured detail and the measuring instrument.

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DEVICE FOR MECHANIZING LINEAR MEASUREMENTS

V. V. Pen'kov and A. P. Povarov

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pp. 8-9, May, 1961

Under mass-production conditions, when automation becomes economical, increasing use is made of various easily mechanized checking devices which raise inspection productivity, make it more objective, and can be operated by inspectors without high technical qualifications.

One of the successful devices used at our plant consists of an instrument for checking after grinding the diameters of sporting gun barrels at twelve cross sections along its length.

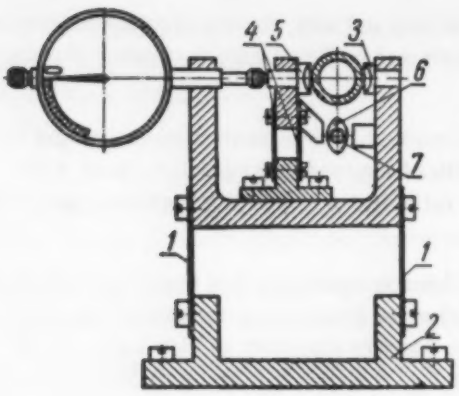

Fig. 1.

The device consists of twelve similar measuring units (Fig. 1), two adjustable knife-edge bearings, and an end rest for the detail, all of them mounted on a common plate.

Caliper gauge 1 is attached by flat springs to base 2. The measuring tip 3, with a hard-alloy plate welded to it, is placed in a free condition at a distance from the axis of the device 0.1-0.15 mm smaller than half the smallest diameter of the barrel at each cross section.

The bracket carries on flat springs 4 the measuring tip 5 whose butt end rests against the extensometer tip. The distance between tips 3 and 5 is set in a free condition to be smaller by 0.2-0.3 mm than the smallest barrel diameter at each cross section.

In the nonoperating condition tips 3 and 5 are separated by means of cams 6 fixed to axle 7, which passes along the entire device. In this position a gap is provided between the maximum diameter of the barrel and the above tips.

The device is adjusted by means of a setting gauge which has collars whose dimensions are equal to the maximum barrel diameters in the corresponding cross sections. The extensometer readings indicate the deviation of the actual dimensions from the setting gauge. The parts of the scales which correspond to the tolerances of the checked dimensions are painted, and in checking it is only necessary to see that the pointer is within the specified range.

This device has made checking 3-4 times more productive and raised its accuracy, since in this device the dimensions are checked at precisely the required cross sections, whereas in checking by limiting snap gauges it was difficult to estimate the exact positions of these cross sections. Moreover, this device can be checked and reset if the barrel diameter approaches one of the limits.

Another device which can be readjusted without great difficulty for measuring by means of all its main components other similar details consists of an equipment for checking the perpendicularity of the butt end to the axis of the bush.

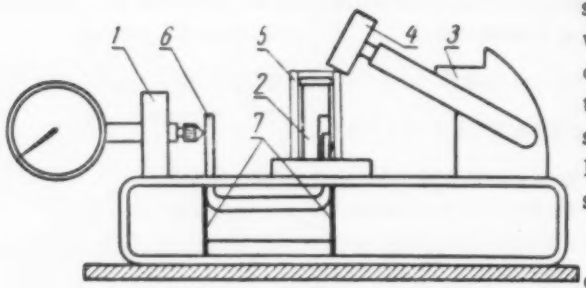

Fig. 2.

The base of this device (Fig. 2) carries the extensometer support 1, the measuring support 2 and support 3 to which flywheel 4 is fixed. The measuring support has at its top end a cylindrical rounded rim whose diameter is 0.05-0.10 mm smaller than that of the tested bush 5. At the bottom of the measuring support there is a hole and a groove for one end of the forked lever 6 which has a pressed-in ball which rests on the internal surface of bush 5 at its lower end.

The forked lever is attached to the lower part of the base on flat springs 7.

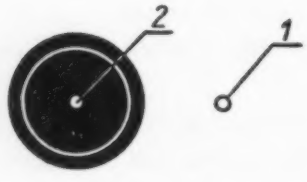

Fig. 3.

Flywheel 4 is mounted on its axle on ball bearings to ease its movement, but it is covered with a strip to increase the friction. Its axle is pressed by means of a spring against support 2. Thus, the flywheel presses against the measured detail at a certain angle and pushes its lower end against the measuring plane and the other end against the rim. The direction of this pressure is chosen so as to make the effort exerted by the bush against the measuring plane greater than that which presses it against the rim, thus eliminating the possibility of tipping the bush over the rim.

When the bush is rotated by means of the flywheel the extensometer readings indicate double the amount of the deviation from the perpendicular of the bush internal hole axis with respect to its butt end, over a length equal to the distance between the rim and the center of the ball. The device can be used for measuring bushes with an internal diameter of 6 mm or more.

This device is readjusted for measuring details of other dimensions by changing the measuring support 2, and if the difference in size is large, support 3 is also changed in order to obtain the required direction of pressure.

For checking the perpendicularity of the bush butt end to its hole axis, an optical instrument constructed from a horizontal optimeter was used. The instrument consists of the tube of an optimeter with its oscillating system removed, and its scale replaced by a special scale obtained by photographing an enlarged image shown in Fig. 3.

On the photographic film scale all the colors are reversed; instead of the index, white circles are seen in the center of which there is a black spot, and instead of the micron scale there is a moving black plot.

A magnetized rod which carries the tested detail is fixed to the left tail spindle of the optimeter. A round mirror is fixed to the butt end of the detail. The image of the black spot passes through the optical system of the optimeter, is reflected from the mirror and projected onto the white circle whose dimensions correspond to the tolerance in perpendicularity.

The checking is carried out in the following manner. The rod is adjusted by means of a setting caliber whose butt end is perpendicular to its axis, sot that the mobile black spot is projected onto the center of circle 2. After adjustment the caliber is replaced by the tested detail and the position of the black spot is observed through the eyepiece. The black spot can be either inside or outside the circle. If it is inside the circle the detail is considered to be satisfactory, if it is outside the circle the deviation in the perpendicularity of the detail is outside the tolerance.

The instrument can be reset by changing its rod, mirror, and scale, whose manufacture and replacement are not difficult and do not require much time.

The advantage of this method of measurement consists in the fact that it is no longer necessary to rotate the detail, since the result is obtained immediately on its placing into position.

The measurement error does not exceed ±0.003 mm.

DELTA-QUANTIZATION OF RECORDING INSTRUMENT READINGS IN TIME MEASUREMENTS

A. G. Fleer

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Modern methods of measuring time intervals by means of recording instruments are based on the use of reference or standard frequencies fed to the input of the instrument and reduced by division to 1 cps or fractions of it. This division is accomplished mainly either by means of synchronous motors or relaxation frequency dividers. The first method reproduces at the output of the instrument with a certain degree of accuracy a continuous time scale, whereas the second method only provides measurements in integers of the minimum discrete values which depend on the input frequency of the instrument and the nature of its output display. When the frequency is reduced by means of a synchronous motor it is possible to use linear interpolation of the measured variable in the intervals between the smallest calibrations of the instrument, whereas this is completely impossible with relaxation frequency dividers. In the latter case we come up against the quantization of instrument readings in the minimum calibration values.

The measurement error in instruments with relaxation frequency dividers, which quantize an analogue quantity, is determined by the quantization period. This error does not rise if higher order figures are included in the system, and it decreases proportionately to the reduction of the quantization period.

The application of electronic calculating methods in measuring time raises the problem of converting the readings of recording instruments into a normal binary code, the problem of the so-called delta-quantization of its readings.

In this article we review the delta-quantization methods of time-measuring instrument readings developed by us for the purpose of applying them to electronic digital computers. We also evaluate the errors due to this type of conversion.

The mechanical system consists of two cylinders A-A' (Fig. 1) which are calibrated by means of alternating conducting and insulated strips in a normal binary code of seconds and their fractions. Both cylinders are driven by a synchronous motor M supplied with a reference frequency. The coupling between the cylinders is such that when the cylinder, calibrated in fractions of a second, makes one complete revolution, the cylinder of whole seconds completes 1/60 of a complete revolution. The quantization period of the lowest order determines the number of binary places in one second. Thus, for instance, with a period of 0.01 sec the number of binary places is 7, and with a period of 0.001 sec it is 10. The number of places for expressing whole seconds does not depend on the quantization period. The rotation of the cylinder with the coded seconds can be either continuous or discrete with a period of 1 sec, depending on the adopted design.

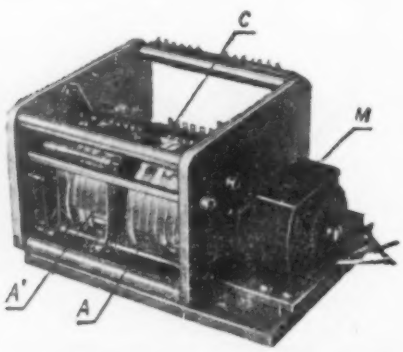

Fig. 1.

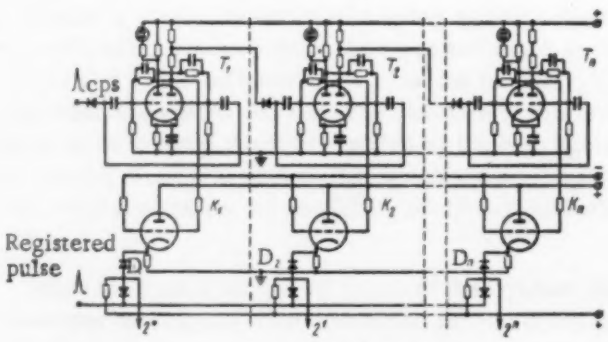

Fig. 2.

The instantaneous angular displacements of the cylinders are registered by feeding an input pulse simultaneously to all the orders of the code in seconds or fractions of a second, and then registering the coded combination by means of special brushes C and feeding it to an electronic circuit. The same circuit eliminates by means of a feedback the discontinuity in a normal code due to the independent coding of cylinders in seconds and fractions of a second.

The electronic system (Fig. 2) consists of a series of triggers T_i which are connected for a consecutive conversion of the standard frequency period, and are divided by means of feedbacks into two groups consisting of tenths, hundredths, etc. of a second and of whole seconds (from 0 to 59).

Similar anodes of each trigger are connected to the grids of cathode followers K_i. For registering the instantaneous conditions of the trigger circuit diode potential, coincidence circuits D_i are used. The simultaneous supplying of the registered pulse to the coincidence circuits of all the triggers, provides in each order either a 1 or 0, depending on the position of the controlling trigger T_i.

Evaluation of errors due to delta-quantization of instrument readings. The use of any device with figure quantization leads to errors due to a superposition of an external registered pulse on the transient process of the quantizing system.

Let f_s and f_m be the frequencies fed to the input of the seconds and minutes groups respectively of the quantizing device.* The quantizing period of order k in either group is represented by expression

$$x_{k_i} = \frac{2^k}{f_i},$$

where k = 0, 1,2 . . . (k_s-1) for the seconds group, and K = 0, 1,2 . . . (k_m-1) for the minutes group.

It will be seen that k_s and k_m determine the number of orders in each quantizing group of the device. Henceforth we shall only consider systems for which the above relation between the quantizing period and the input frequency to the group holds.

Let us call indeterminate the zone 2a, measured in units of time, for which there is a possibility of the instrument readings being distorted by an amount equal to the quantizing period of a given order. Let us calculate the probability of such an indeterminacy appearing. It will be equal to the product of the probability p_1 that at the instant the recorded pulse appears, the quantizing system will be in one of the conditions which may lead to indeterminacy, by the probability p_2 of the pulse falling into the indeterminacy zone inside the interval under consideration and by probability p_3 of the appearance of indeterminacy inside the zone of indeterminacy, i.e.

$$P_{k_i} = p_1 \cdot p_2 \cdot p_3.$$

By definition $p_3 = \frac{1}{2}$, let us now find p_2.

The number of chances which favor the appearance of an indeterminacy is expressed by the extension in time of the indeterminacy zone 2a. The total number of possible chances in order k is determined by the dimension of the quantizing period.

Hence

$$p_2 = \frac{2af_i}{2^k}$$

and

$$P_{k_i} = \frac{af_i}{2^k} p_1. \qquad (1)$$

This is the general formula for calculating the probability of indeterminacy appearing in order k of group i.

The mean error for a single result in a very large number of measurements is expressed by the expectation value [1]

$$M = \sum_i \sum_{k=0}^{k_i - 1} x_{k_i} P_{k_i}, \qquad (2)$$

and the square of the quadratic mean error of one measurement is determined by the value of the dispersion

*Here and henceforth we give the name of seconds group to the group of fractions of a second and minutes group to that of fractions of a minute (whole seconds).

$$D = \sum_{l}\left[\sum_{k=0}^{k_l-1} x_{k_l}^2 P_{k_l} - \left(\sum_{k=0}^{k_l-1} x_{k_l} P_{k_l}\right)^2\right]. \tag{3}$$

Let us now use (1), (2) and (3) for evaluating actual designs of quantizing systems.

a) Mechanical systems with a continuously rotating minutes group cylinder. Since the entire length l of the cylinder circumference in group s passes under a tapping contact of a width b in 1 sec, we have

$$a = \frac{b}{l} \times 1 \text{ sec}.$$

Considering that the probability p_1 for this cylinder is equal to unity, we obtain from (1)

$$P_{k_s} = \frac{bf_s}{2^k l} \times 1 \text{ sec}. \tag{4}$$

The cylinder of the m group in 1 sec turns through 1/60 of a complete revolution, hence

$$a = \frac{60b}{l} \times 1 \text{ sec},$$

and

$$p_1 = \frac{f_m}{f_s}.$$

there

$$P_{k_m} = \frac{60bf_m^2}{2^k l f_s} \times 1 \text{ sec}. \tag{5}$$

Taking into consideration (4) and (5) and that

$$x_{k_s} = \frac{2^k}{f_s} \text{ и } x_{k_m} = \frac{2^k}{f_m}$$

we obtain

$$M = \frac{b}{l}\left(k_s + \frac{60f_m}{f_s} k_m\right) \times 1 \text{ sec}.$$

Dispersion (3) is calculated from formula

$$\sigma^2 = \frac{b}{f_s l}\left(\sum_{k=0}^{k_s-1} 2^k + 60 \sum_{k=0}^{k_m-1} 2^k\right) \times 1 \text{ sec} - \frac{b^2}{l^2}\left(k_s^2 + \frac{3600f_m^2}{f_s^2} k_m^2\right) \times 1 \text{ sec}^2. \tag{7}$$

b) A mechanical system with a discrete rotation of the minutes group cylinder. In such a design of a quantizing system P_{k_s} is also determined from (4). In order to simplify the analysis let us assume the rate of cylinder change-over in the minutes group to be constant over the whole interval of $1/60\,l$. Let us denote the change-over time by h.

Then

$$a = \frac{60hb}{l}$$

and

$$P_{k_m} = \frac{60hbf_m^2}{2^k l f_s}. \tag{8}$$

The expectation value in this case will be

$$M = \frac{b}{l}\left(k_s \times 1 \text{ sec} + \frac{60hf_m}{f_s} k_m\right). \tag{9}$$

and the dispersion

$$\sigma^2=\frac{b}{f_s l}\left(\sum_{k=0}^{k_s-1}2^k\times 1\ \text{sec}+60h\sum_{k=0}^{k_m-1}2^k\right)-\frac{b^2}{l^2}\left(k_s^2\times 1\ \text{sec}^2+\frac{3600h^2f_m^2}{f_s^2}k_m^2\right). \tag{10}$$

c) An electronic system. In an electronic quantizing system we shall take the zone of indeterminacy 2a to be double the duration of the external pulse which is fed to the coincidence circuit for registering the state of the trigger circuits, since the external pulse is almost always longer than the transient process in the triggers.

Using (1), (2) and (3) for evaluating this system we obtain

$$P_{k_s}=\frac{af_s}{2^k}, \tag{11}$$

$$P_{k_m}=\frac{af_m^2}{2^k f_s}, \tag{12}$$

$$M=a\left(k_s+\frac{f_m}{f_s}k_m\right), \tag{13}$$

$$\sigma^2=\frac{a}{f_s}\left(\sum_{k=0}^{k_s-1}2^k+\sum_{k=0}^{k_m-1}2^k\right)-a^2\left(k_s^2+\frac{f_m^2}{f_s^2}k_m^2\right). \tag{14}$$

Examples in evaluating actual systems. Let us evaluate a mechanical quantizing system with $f_s = 100$ cps, $f_m = 1$ cps, $l = 251$ mm, and $b = 0.125$ mm. The rotation of the minutes group cylinder is irregular. The number of binary units in the seconds group is determined by the whole number of $\log_2 100$, and the number of binary units in the minutes group by the whole number of $\log_2 60$. The first figure (k_s) is equal to 7, and the second (k_m) to 6.

The mean error for a single result (6) is equal to $M = 0.005$ sec, and the quadratic mean error of one measurement (7) $\sigma = \pm 0.14$ sec.

For a mechanical system with discrete rotation of the minutes group cylinder ($h = 1/60$ sec) and the same remaining characteristics we obtain from (9) and (10) that $M = 0.004$ sec, and $\sigma = \pm 0.03$ sec.

For the parameters of an electronic quantizing system we shall take $f_s = 100$ cps, $f_m = 1$ cps, $a = 50\mu$sec, k_s and k_m equal, respectively, 7 and 6.

Then, according to (13) and (14) we obtain $M = 0.0004$ sec and $\sigma = \pm 0.01$ sec.

By using the same formula let us evaluate an electronic system with $f_s = 1$ kc. As compared with the parameters of the preceding evaluation the number of bits of the seconds group will change. In this case $k_s = 10$. From the calculations we obtain that $M = 0.0005$ sec and $\sigma = 0.003$ sec.

SUMMARY

1. From the above systems of delta-quantization of the measuring instrument's readings we find that the electronic is the best system both for M and for σ. With a sufficiently small value of $\underline{h}$ (of the order of 1/60 sec) and a ratio of b/l of the order of $\underline{a}$, a mechanical quantizing system with a discrete rotation of the minutes group cylinder will have the same expectation value and dispersion.

2. For the evaluation and analysis of quantizing systems it is possible to use instead of (7), (10) and (14) the expressions given below

$$\sigma^2=\frac{b}{f_s l}\left(\sum_{k=0}^{k_s-1}2^k+60\sum_{k=0}^{k_m-1}2^k\right)\times 1\ \text{sec}$$

$$\sigma^2=\frac{b}{f_s l}\left(\sum_{k=0}^{k_s-1}2^k\times 1\ \text{sec}+60h\sum_{k=0}^{k_m-1}2^k\right),$$

$$\sigma^2 = \frac{a}{f_s}\left(\sum_{k=0}^{k_s-1} 2^k + \sum_{k=0}^{k_m-1} 2^k\right)$$

respectively for a mechanical system with a uniformly rotating minutes group cylinder, for a mechanical system with a discrete rotation of the cylinder, and for an electronic quantizing system.

3. The raising of the input frequency of the seconds group by a factor of n reduces the value of dispersion $\sigma \sim b\sqrt{n}$, but the expectation value M rises. This is due to the increased number of bits in the seconds group with a rising input frequency.

4. Both the electronic and mechanical quantizing systems with discrete displacement of the minutes groug cylinder (with an appropriate design and accuracy of manufacture) can provide a registration sufficiently accurate for modern requirements. Hence, it is as yet inadvisable to use designs and circuits which automatically exclude the possibility of an indeterminacy appearing (Gray's code [2], symmetrical tapping brushes [3], etc.), but lead to a considerable complication of recording instrument's electronic circuit.

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MECHANICAL MEASUREMENTS

CHECKING TAXIMETERS

A. I. Suvorov

Translated from Izmeritel'naya Tekhnika, No. 5,
pp. 13-14, May, 1961

In view of the changed tariff for passenger taxis and the change-over to a new scale the taxi workshops and state control laboratories for measurement equipment need to carry out a considerable amount of work in changing and checking taximeters.

In order to carry out this work in a limited time it is necessary to find technical means for rapidly providing the taxi fleet with accurate meters.

Summing up the experience gained to date in this work it should be noted that the Committee's specifications do not completely cover the requirements and need to be supplemented and amended.

In taximeters, as in measuring instruments, only the accuracy of the clockwork mechanism and the duration of its operation are checked. The remaining checking operations, such as external inspection, checking the coupling of mechanisms, switching, signalling, checking the operation of counters when the meters are working from a flexible shaft, are dealt with when the assembly and mechanical reliability of the counting and other mechanisms are checked.

The requirements set for the clockwork mechanism of a taximeter are low, its error must not exceed ±4 min per 8 hr or ±12 min per 24 hr and it must work without rewinding for at least 8 hr.

In view of these easy requirements with respect to taximeters it would appear advisable to strike them off the list of measures and measuring instruments subject to compulsory state testing by the Committee's agencies, and to carry out their testing by the service inspection agencies directly in the taxi garages and repair shops. For this checking it is enough to have a test rack, a clock with an error of ±1 min per day, and a reliable checked revolution counter. All this equipment is available in most workshops. It should also be remembered that the inspection of motor transport, including the instruments mounted on automobiles, comes under the state motor transport inspection.

The most labor consuming operation in taximeter inspection is the checking of tariff counters, cash registers, and the total and paid distance when the taximeters are working from a flexible shaft.

This checking amounts to running the meters on the test stand for a nominal distance of 40 km at the speed of 60 km/hr and then at a speed of 12 km/hr for 1 hour and comparing the results thus obtained with the readings of reference revolution counter. The deviation of the taximeter readings from those of the revolution counter must not exceed the minimum decimal readings of the former, that is 0.1 or 0.2. If the meter is within the tolerances, it shows that the operation of the worm and wheel gears of the counting mechanism is correct over the checked intervals.

However, these tests of a taximeter operation from a flexible shaft do not guarantee their further reliable operation, since these tests are made only over 4-5% of the total range. Thus, the range of the meter readings of the total and paid distance amounts to 999.9 km, but the checking of their operation according to the specification requirements is only carried out over 40 km, which amounts to 4% of the total.

In order to check the operation of taximeters over the whole range at a rate of 60 km/hr they would have to be run for 17 hr and then compared with the readings of a reference revolution counter.

Observations and experience in running taxi garages show that it is necessary to test taximeters over the whole range, thus providing the checking of the full revolutions of all the counting drums.

In order to satisfy this requirement and raise the efficiency of testing we suggest that taximeters be checked with their driving axle and reduction gear removed, and their quadrant gear axle coupled directly to the flexible shaft by means of a forked connection.

The direct coupling of the flexible shaft to that of the quadrant raises the speed of rotation of the counter by a factor of 8.7, thus increasing the efficiency of testing and making it possible to check over the whole of the meter range. The raising of the speed in checking shows up more effectively any defects, whose elimination increases the reliability of the subsequent operation of the meter.

We approved for an experiment the raising of the flexible shaft speed for testing meters up to 150 rpm.

The nominal testing speed of 60 km/hr was thus raised by a factor of 25 and the total time taken for testing meters over the whole of their range, i.e., over 999.9 km amounted to 40 min. It was found that the operation of the meters under this condition proceeded smoothly, without jerks. The knowledge that every 2.4 sec the meter covers a nominal distance of 1 km made it possible to establish a routine for observing the operation of the counting drums and clearing any defects.

After checking the operation of a meter over the whole of its range in 20 min we checked its working at varying driving speeds.

On the basis of the constructional peculiarities of taximeters which provide an independent operation of the counter from the clockwork mechanism and from the flexible drive, it has been possible to establish that the checking of counters at a nominal speed of 12 km/hr is not necessary. It has been found in practice that in all the instances when the operation of meters was found satisfactory at a speed of 60 km/hr, no defects were discovered at a speed of 12 km/hr. It has been found that the failures and incorrect readings of meters are mainly due to the defects which were not discovered in checking them at a nominal speed of 60 km/hr since those tests only covered a nominal 40 km of their range.

A reliable operation of taximeters depends to a great extent on checking the easy running of the flexible drive, since any jamming, or "heavy" running leads to the twisting of the flexible drive, in the sockets and couplings, a jerky running and rapid deterioration of the flexible drive.

In our opinion taximeters should have a legible and clear inscription indicating the operating tariffs.*

A CAPACITANCE BRIDGE METHOD FOR MEASURING SPEEDS OF ROTATION

V. I. Fridlyand

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pp. 14-16, May, 1961

In experimental investigations of high-speed machines it is often necessary to make precision measurements and recordings of the rotation speeds of shafts for small variations of these speeds.

One of the circuits which provides a high precision of measurement and an easy recording is the balanced bridge circuit with a commutated capacitor.

Figure 1 is the schematic of an automatic tachometer bridge with a commutated capacitor. The bridge is fed with voltage U_s from a dc source. Commutators K_1 and K_2 are connected to the shaft whose speed of rotation it is required to measure. The number of their switchings per unit of time is proportional to the measured speed of rotation.

* The Editorial Board requests the GKL (State Inspection Laboratories) personnel and the motor garage and repair shop personnel engaged in repairing taximeters to write to this journal about their experience and express their opinion on the problem raised in this article by A. I. Suvorov.

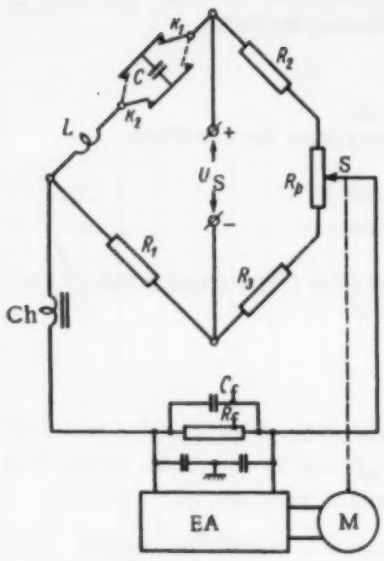

Fig. 1.

As the commutators are being switched capacitor C is charged and discharged through inductance L and resistance R_1, and a recharging current is made to flow in this circuit. The mean value of this current is directly proportional, and the equivalent impedance of the RCL circuit is inversely proportional to the measured speed of rotation.

Capacitor C and inductor L constitute the reactive arm of the bridge, the remaining arms are made up of resistors R_1, R_2, R_3 and R_p.

The measuring diagonal of the bridge has an LC filter which consists of a choke coil Ch and a capacitor C_f across whose load R_f the mean bridge unbalance voltage is obtained.

The unbalance voltage is fed from resistor R_f to the input of a phase-sensitive electronic amplifier EA, is amplified and operates at its output reversible motor M, which drives the slide-wire runner S until the bridge is completely balanced. The motor is also connected kinematically to the marker of the recording mechanism and the pointer of the measuring instrument.

Let us now examine the theory of the bridge.

The RCL network which forms the two series-connected arms of the bridge is represented by a differential equation

$$iR_1+L\frac{di}{dt}+\frac{1}{C}\int idt=U_S \tag{1}$$

The optimum condition for a critical aperiodic discharge of capacitor C is of interest from the point of view of the speed of the transient process decay.

In this case the parameters of the RCL network are related by the expression

$$R^2=\frac{4l}{C}. \tag{2}$$

The solution of (1) with the initial conditions of $i(0)=0$, $u_c(0)=-U$ has the form

$$i=2CU\ \frac{t}{\tau^2}e^{-\frac{t}{\tau}},$$

where

$$\tau=\frac{2L}{R_1}=\sqrt{LC}\ .$$

The charge of the capacitor is

$$Q_0=\int_0^t idt=2CU\left[1-e^{-\frac{t}{\tau}}\left(1+\frac{t}{\tau}\right)\right]=2CU(1-k_0). \tag{4}$$

The mean value of the current in the RCL network for k_1 switchings of the commutator in one shaft revolution is

$$I_m=\frac{k_1Q_0}{T}=\frac{k_1Q_0n}{60}=kCUn\ (1-k_0). \tag{5}$$

where n is the measured number of rotations; $k=k_1/60$ is the coefficient of proportionality; $k_0=e^{-t/\tau}\ (1+t/\tau)$ is a correction coefficient which is a function of the ratio of the capacitor recharging time to the time constant of the discharging circuit.

If the components of the RCL network are chosen in such a manner that it is possible to neglect the correction coefficient k_0 with respect to unity, the expression for the mean current will assume the form:

$$I_m = kCUn. \tag{6}$$

The equivalent impedance of the CL arm for a balanced bridge is obtained from the condition:

$$R_e = \frac{U}{I_m} - R_1 = \frac{1}{kCn} - R_1. \tag{7}$$

The measured number of revolutions is determined for a balanced bridge from (7) by a single-valued expression:

$$n = \frac{R_3}{kCR_1\,(R_2+R_3)}. \tag{8}$$

Let us now examine the error in measuring the speed of rotation by means of the above circuit. As it will be shown later, the measurement errors in this circuit depend on the value of coefficient k_0 and on the accuracy of manufacture of the bridge components. (Contact resistances of commutators are assumed to be negligibly small.)

A small value for coefficient k_0 is assured by an appropriate choice of the RCL network parameters.

On the time diagram (Fig. 2) period T, which corresponds to the highest measurable speed of rotation, is divided into 4 sections, two of which are $\underline{t}$ the capacitor recharging time corresponding to the commutator contact making-time, and t_0 the commutator switching time.

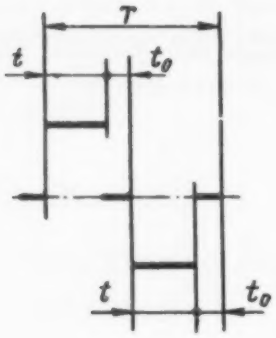

Fig. 2.

In order to determine the RCL network parameters we have plotted a graph of the relation between coefficient k_0 and the ratio of t/τ (Fig. 3). For a chosen value of $k_0 = k_0'$ ratio t/τ is determined, and from a known recharging time $\underline{t}$ the time constant τ of the RCL network is found. Next, by choosing one of the circuit parameters, for instance, the capacitance C, it is possible to determine the values of resistor R_1 and inductor L from (2) and (3a):

$$R_1 = \frac{2\tau}{C}; \quad L = \frac{\tau^2}{C}. \tag{9}$$

If relation (2) is not met the transient process during the recharging of the capacitor will have the form either of a damped oscillation or an aperiodic but not critical discharge. In order to evaluate the errors of deviation from an aperiodic discharge both solutions of (1) must be examined.

In this case the capacitor charges are represented respectively by

$$Q_1 = 2CU\left[1 - e^{-\frac{t}{\tau}}\left(\frac{1}{\omega\tau}\sin\omega t + \cos\omega t\right)\right]$$
$$Q_2 = 2CU\left[1 - e^{-\frac{t}{\tau}}\left(\frac{1}{\omega\tau}\,\mathrm{sh}\,\omega t + \mathrm{ch}\,\omega t\right)\right], \tag{10}$$

where

$$\omega = \sqrt{\frac{1}{LC} - \frac{R_1^2}{4L^2}}.$$

The relative error of a capacitor charge will be

$$\frac{\Delta Q_1}{Q_0} = -e^{-\frac{t}{\tau}}\left(\frac{1}{\omega\tau}\sin\omega t + \cos\omega t\right) \tag{11}$$

$$\frac{\Delta Q_2}{Q_0} = -e^{-\frac{t}{\tau}}\left(\frac{1}{\omega\tau}\operatorname{sh}\omega t + \operatorname{ch}\omega t\right). \tag{11}$$

Figure 4 shows the graphs of the relation of the relative error $\Delta Q/Q_0$ to the manufacturing errors of resistor R and inductor L for the case of $K_0 = 1 \cdot 10^{-3}$%.

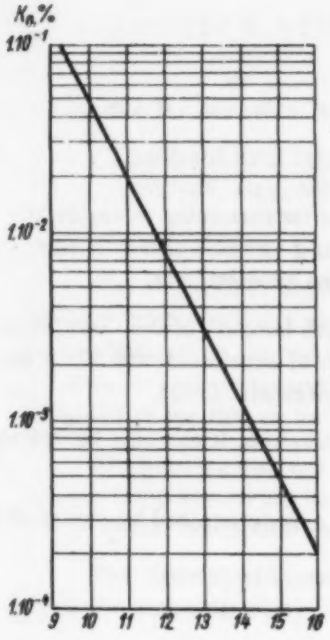

Fig. 3.

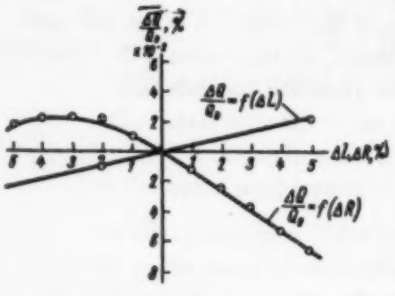

Fig. 4.

It will be seen from the graphs that in order to provide such a small value for coefficient k_0 it is sufficient to manufacture the resistor and inductor with an error of ± 1% respectively, which can easily be achieved.

The relative error of speed of rotation measurements if condition $k_0 \leq k_0'$ is observed can be determined from (8) as an error of indirect measurements

$$\xi_n = \frac{\Delta C}{C} + \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} + \frac{\Delta(R_2+R_3)}{R_2+R_3}. \tag{12}$$

Thus the measurement error depends on the manufacturing accuracy of the components which form the measuring bridge.

Providing manganin aged according to a special process is used in the resistors they can be made with an accuracy of $5 \cdot 10^{-3}$% and their resistance will vary with any further ageing by an amount of the same order as the above error. Moreover, the bridge arm resistors can be selected with an appropriate sign of their errors.

By using group G capacitors, which have a capacity temperature coefficient of $\pm 50 \cdot 10^{-6}$, the effects of ambient temperature variations on capacitance C are made sufficiently small. A greater stability and accuracy of capacitance C may be obtained by building it with capacitors which have temperature and aging coefficients of opposite signs.

In order to provide the required accuracy of measurement the instrument range is divided into several suppressed zero bands.

The instrument scales are calibrated by means of a reference signal generator whose error is an order lower than that of the tachometer.

On the basis of the above theory a batch of automatic tachometers type RT-1 was made for measuring and recording high rotation speeds in the ranges of 600-12000, 600-14000 and 600-48000 rpm, each range being subdivided into 12 bands in intervals of 1000, 2000 and 4000 rpm with scale calibrations of 5, 10 and 20 rpm respectively.

In order to be able to check the instruments in operation they have a built-in tuning-fork generator of 400 cps with an error of ± 0.003%.

Induction or photoelectric transducers are used for converting the shaft speed of rotation into electrical pulses.

Laboratory tests of RT-1 tachometers have shown that the maximum referred speed of rotation error of these instruments amounts to ± 0.05%.

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CALIBRATION OF A PIU-1 ACCELEROMETER

P. N. Agaletskii

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In recent years the piezoelectric accelerometer PIU-1 has been fairly widely used for measuring vibration accelerations. It is a direct-reading instrument. Its scale is calibrated in acceleration units g ($g = 9.81$ m/sec^2); however, it is not stated whether these notations refer to peak or effective values of vibration accelerations.

The dynamic measurements laboratory of the VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments) has established that the manufacturer of accelerometers PIU-1 has calibrated them incorrectly and the instrument readings contain considerable (~ 30%) systematic errors.

The PIU-1 instrument measures effective (not peak) values of output voltages. Therefore, it can only be calculated in effective values of vibration accelerations received by the transducer.

In calibrating accelerometers by means of sinusoidal vibrations whose amplitude A is determined by means of a reference accelerometer or measured indirectly and calculated from

$$A = 4\pi^2 f^2 D,$$

where D is the amplitude of vibration displacements, and f is the frequency of vibrations, the effective value of acceleration A_{eff} for a sinusoidal form is found by multiplying the amplitude A by a factor of 0.707.

Accelerometer PIU-1 is calibrated in amplitude values of vibration accelerations of a sinusoidal shape and its readings are only correct if the measured vibrations have a strictly sinusoidal shape. If this condition is not met (and in practice it is hardly ever observed) the instrument readings become erroneous. Hence, accelerometer PIU-1 readings should be multiplied by 0.707 and considered to be effective values of the measured vibration acceleration.

THERMOTECHNICAL MEASUREMENTS

NATURE OF DYNAMIC ERRORS IN MEASURING PULSATING TEMPERATURES OF A GAS FLOW WITH A PULSATING SPEED

A. N. Gordov and B. I. Kovshev

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One of the most important factors in testing new types of thermal engines, both of the internal combustion and reactive types, consists in measuring the temperature of the gas flow. The periodicity of a working cycle in an internal combustion engine and the turbulent nature of the flame in a jet of a reactive engine make it necessary to develop methods for contact measurements of pulsating temperatures in a gas flow under conditions of a synchronously changing speed of the flow or for measuring the heat-transfer coefficient on the surface of the heat collector.

The existing methods of accounting for the thermal inertia of heat collectors when measuring periodically varying temperatures are based on the assumption of a constant heat-transfer coefficient. It is obvious that in many instances this assumption does not correspond in the least to the nature of the process.

The theoretical investigation of the temperature field of a body (of an unlimited cylinder as the most common shape for heat collectors) in a gas flow with a pulsating temperature and speed has already been made [1,2,3].

For sinusoidal (synchronous and cophasal) variations of the temperature flow and the heat-exchange coefficient with time, the peculiarities of a body's temperature field due to variations in heat emission amount to the following: the curve registered by the heat collector gives, owing to the presence of a second harmonic, a distorted idea of the shape of the curve representing the variation in the flow temperature; the mean level of temperature oscillations of a heat collector is higher than that of the flow. This is due to a raised heating of the heat collector in the first half of the cycle and a lowered cooling in the second.

The latter conclusion has a theoretical significance. It shows that the dynamic nature of the process may under certain conditions produce static measurements errors. Underestimation of this phenomenon leads to errors in determining the mean temperature of the gas flow.

If the oscillations of the flow temperature and that of the heat-exchange coefficient occur with a phase difference φ, the mean level displacement M of a cylindrical heat-collector temperature oscillation with respect to the mean level of the flow temperature oscillations is equal to

$$M=\frac{A_1A_2R\cos\varphi}{2\left[h_0R-A_2R\left(\cos\varphi\ \mathrm{bei}\ R\sqrt{\frac{\omega}{a}}-\sin\varphi\ \mathrm{ber}\ R\sqrt{\frac{\omega}{a}}\right)\right]}, \tag{1}$$

where A_1 and A_2R are the amplitudes of low temperature oscillations and of the Biot criterion h_0R; ω is the frequency of oscillation; R is the radius of the cylindrical heat collector; α is the temperature conductivity coefficienty of its material; ber x and bei x are the functions by means of which the Bessel function I_0 of a complex argument is expressed.

It will be seen from (1) that if the temperature and heat emission oscillate completely out of phase ($\varphi=\pi$), the value of M becomes negative.

In order to elucidate the nature of the mean level displacements in actual heat collectors used in temperature measurements, and investigate the relation of the displacements to frequency, the high temperature laboratory of the VNIIM (All-Union Scientific Research Institute of Metrology) has built a special installation PITT, whose schematic is shown in Fig. 1.

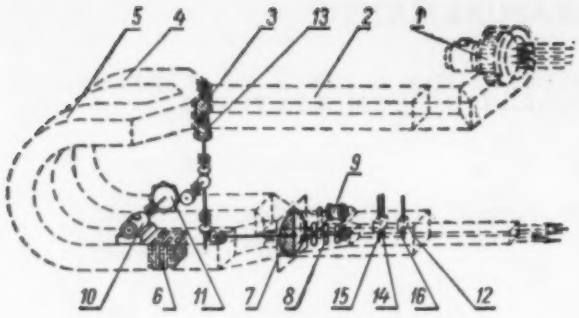

Fig. 1.

An air flow is established by means of blower 1 in the square pipe 2. Valve 3 is placed at the end of the straight section of pipe 2 and made to rotate at a uniform speed about its vertical axis. The valve produces in both branches 4 and 5 of the pipe sinusoidal oscillations in the speed of the flow. Branch 5 has a multilayer constant-power heater 6. The cold and hot air streams are mixed in varying proportions by means of a semicircular vane 7, which rotates at a uniform speed about its horizontal axis.

Next, the flow is forcibly mixed by means of three propellers 8, mounted on the same axle which is driven by a separate motor 9. Both valve vanes are driven at the same speed by motor 10 through reduction gear 11. The combined effect of the vanes produces in the operating portion 12 of the installation an air flow with a pulsating speed and temperature. By means of a clasp joint 13 it is possible to disconnect and reset the driving axles of the vanes, thus changing the phase relation between the temperature and speed oscillations of the flow. Reduction gear 11 provides a variation in the temperature and speed oscillations of the flow in the range of 0.1 to 1.0 cps. A quick-response resistance thermometer 14 for registering the temperature oscillations of the air stream, the heat collector 15 under test, and thermoanemometer 16 are placed in the operational section of the pipe.

The sensing elements of the quick-response thermometer and the thermoanemometer are made of alloy VA-3 wire 34 μ in diameter with a resistance temperature coefficient of $\beta = 3.55 \cdot 10^{-3} \deg^{-1}$. Inertial resistance thermometers, thermocouples and mercury-in-glass thermometers were used as heat collectors under test. The inertial resistance thermometers were made by fusing a 0.1 mm platinum wire in glass capillary tubes with different wall thicknesses.

The recording of the variable component of signals from the thermoanemometer, resistance thermometers and thermocouples was made on a "Vibrator" plant photoelectric recorder F-16. The dynamic characteristics of the recorder were evaluated in separate experiments. The constant component of the signals was compensated by means of a voltage of the opposite sign from an auxiliary source. The value of the compensating voltage was measured with a laboratory potentiometer. Steps were taken to prevent stray thermal emfs which arise in a measuring circuit from distorting the measurement results.

TABLE 1

ω	0.1	0.3	0.5	0.8	1.0
$\frac{(A_2R)_\omega}{(A_2R)_{0.1}}$	1.0	0.938	0.885	0.814	0.770

The PITT equipment provided air flow temperature oscillations of an amplitude of ~20°C, relative amplitude oscillations of the Biot criterion A_2R/h_0R amounting to ~0.25 at a frequency of 0.5 cps. Owing to the hydrodynamic inertia of the air stream, the amplitude of the Biot criterion oscillations decreased slightly with a rising frequency. This drop referred to the amplitude at 0.1 cps is shown in Table 1.

Owing to the nonlinear relation between the heat-exchange coefficient and the speed of the air flow, the oscillations of this coefficient are distinctly nonsinusoidal for sinusoidal variations of the speed. Moreover, in each cycle the duration of the raised heat-transfer coefficient values is considerably larger than that of its lowered values. Let us note that such a waveform of the coefficient will always occur for sinusoidal oscillations of the gas flow speed.

Experiments in determining the value of M were carried out according to the following program.

When the temperature oscillations in the working section of the tube became stable for a given frequency the compensating voltages were selected and set. Next, the temperature variations of the quick-response thermometer and then of the tested inertial heat collector were recorded. The position of the quick-response thermometer and the tested heat collector were then interchanged and their readings again recorded. From the readings and the corresponding values of the compensating voltages the differences in the mean level of temperature oscillations were calculated.

It was established in preliminary experiments that the difference in the mean level of temperature oscillations in two quick-response thermometers placed in the working space of the PITT equipment was very close to zero. Test

TABLE 2

Notation	Name	Heat collector	Diameter (wire, test tube, container), mm	ε, sec
T_1	Resistance thermometer	Bare platinum wire	0.1	0,03
T_2		The same	0.3	0.09
T_3		Glass-covered platinum wire	0.5	0.14
T_4		The same	0.8	0.25
T_5		"	1 8	0.60
T_6		"	3.6	2,90
T_7		"	5.2	4,00
T_8	Thermocouple	Bare platino-Rh-Pt thermocouple electrode	0.5	0.30
T_9		Platino-Rh-Pt thermocouple electrode in a glass test tube	4	3,60
T_{10}	Mercury thermometer	Container with mercury	7	14.00

experiments have also shown that under the same conditions all the tested heat collectors had in a constant speed flow a mean level of temperature oscillations practically equal to that of quick-response thermometers. Thus, it will be seen that the displacement of the mean level of temperature oscillations in inertial heat collectors is caused, as would also be expected from theoretical considerations, only by the combined effect of synchronous oscillation of the flow temperature and the heat-exchange coefficient.

It will also be seen from (1) that the value of M is proportional in the first approximation to the cosine of the phase difference in the oscillations of the flow temperature and the heat-exchange coefficient.

It was also possible to check this assumption by means of the PITT equipment. Figure 2 shows a typical curve of the relation of M/A_1 to the phase difference φ in the oscillations of the flow temperature and the heat-exchange coefficient, from which it will be seen that the cosine law is followed fairly satisfactorily.

The large value of the negative displacement as compared with that of the positive is due to the peculiarities of the PITT equipment. In order to obtain more reliable results in measuring the value of M for various types of heat collectors we subsequently further experimented with the value of $\varphi = \pi$. The characteristics of the tested heat collectors are shown in Table 2.

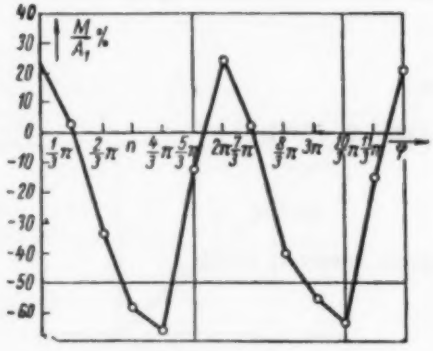

Fig. 2.

TABLE 3

ω,cps	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
0,1	3	30	32	43	63	67	66	68	41	69
0,2	8	37	45	55	68	70	69	72	55	71
0,3	11	43	49	59	68	71	70	73	62	73
0,4	12	47	50	63	69	71	70	72	63	75
0,5	13	48	48	61	70	71	69	73	66	73
0,6	10	46	50	61	68	70	68	72	66	73
0,7	15	48	53	64	71	72	69	72	69	74
0,8	16	52	55	63	70	74	72	72	71	77
0,9	18	54	58	68	73	74	71	76	74	75
1,0	18	55	60	67	74	76	71	74	70	75

The values of ϵ indicate the constant thermal inertia of the heat collectors measured by the method of a regulated heat condition [4] in still water.

The measurement results of the mean level displacements of temperature oscillations expressed as percentages of amplitude A_1 for all the types of tested heat collectors are shown in Table 3.

The relative displacements due to frequency differences in the same heat collector were corrected for the amplitude variations of the Biot criterion oscillations with frequency according to the data on their mean relationship given in Table 1.

Each figure which in Table 3 represents the relative displacement is an arithmetic mean of 4-5 series of measurements. From the deviations between the individual series we found the quadratic mean error of measurement, equal to 1-4% (taking into consideration the limited number of series [5]).

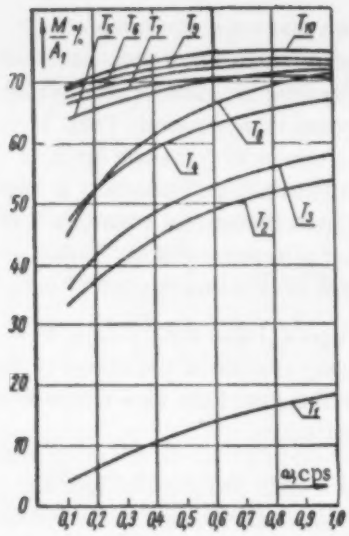

Fig. 3.

From the data of Table 3 curves were plotted (Fig. 3) showing the relation between the mean level of relative displacements of temperature oscillations and frequency.

SUMMARY

1. The displacement of the mean level in the synchronous oscillations of temperature with respect to heat-exchange is due to the thermal inertia of the body. The displacement increases with rising thermal inertia. As a working hypothesis it can be assumed that, in the same manner as the quenching of the amplitude of temperature oscillations is determined by the product of $\epsilon\omega$, the nature of the displacement also depends on the value of this product.

2. If the value of $\epsilon\omega$ remains in the range of $0.003 < \epsilon\omega < 0.5$, the relative displacement of the mean level of temperature oscillations in heat collectors increases monotonically with frequency. For values of $\epsilon\omega < 0.003$ the value of the relative displacement M/A_1 is, it would appear, so small that it need not be considered in working out the results of the recorded variable temperatures.

3. For values of $\epsilon\omega < 0.5$ the value of M/A_1 becomes independent of frequency. A certain rise observed in all the curves at frequencies of 0.1 and 0.2 cps is due, it would appear, to omitted systematic errors whose values, however, do not exceed the above-mentioned quadratic mean error.

4. The absolute displacement value not only depends on the oscillation amplitude of temperature and heat-exchange (and the value of $\epsilon\omega$) but also on the shape of their curves. For a sinusoidal shape of the heat-exchange variations curve, the observed displacement values were smaller than those recorded on the PITT equipment. It follows from the above that the experimental determination of the error in measuring the mean level of temperature oscillations in a gas flow should be carried out with an equipment capable of reproducing even approximately the shape of the curve of temperature and heat-exchange oscillations which occur in the operating conditions of the heat collector.

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THERMOELECTRIC CHARACTERISTICS OF HIGH-TEMPERATURE THERMOCOUPLES WITH ELECTRODES MADE OF HIGH MELTING POINT ALLOYS

P. S. Kislyi, V. I. Lakh, G. V. Samsonov, B. I. Stadnyk, R. F. Kharenko and A. B. Chekhovich

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At present the standard platinorhodium-platinum thermocouple PP is widely used commercially for measuring temperatures of long duration in the range of 300 to 1300°C and of short duration up to 1600°C. Temperatures are

measured up to 1300°C with a sufficiently high accuracy (± 0.3%), but for temperatures above 1300°C the thermocouple thermal-emf is unstable.

Of all the thermocouples on the basis of platinum and rhodium proposed by various researchers, the most commonly used commercially is that made by the firm of Deguss Hanau (F.G.R.) under the trade mark "PtRh 18" (PR30/6), whose electrodes consist of platinum + 30% rhodium and of platinum + 6% rhodium. The thermocouple is recommended for measuring temperatures up to 1800°C. One advantage of this thermocouple consists in the small effect produced on its readings by the temperature of the cold junction, since up to 200°C the thermal-emf of such a thermocouple is relatively small (not exceeding 0.2 mv). Test results of Soviet-made thermocouples PR30/6 have shown that they can work reliably both in oxidizing and neutral media; however, their top temperature is limited to 1700-1800°C. The thermal-emf stability of thermocouples made of precious metals or their alloys depends to a great extent on the presence in the measured medium of metal vapors or corrosive gases which in practice exclude the possibility of using such thermocouples, including the PR30/6 thermocouples.

Several thermocouples [1] used for measuring temperatures of 1700-2500°C have unstable thermoelectric characteristics in corrosive media and are not being widely used in industry, and the most widely used tungsten-molybdenum thermocouple has an extremely small emf. Since a tungsten-molybdenum thermocouple has an inversion point at about 1300°C (Fig. 1) it can only be used for measuring temperatures in the range of 1300-2200°C; moreover, the thermocouple lacks a standard calibration, and prolonged measurements can be made with it only in vacuum or in reducing or neutral media except helium.

Thermocouples on the basis of tungsten-rhenium alloys, as suggested by the Moscow Central Automation Laboratory, are most promising for measuring high temperatures. In particular thermocouple VR5/20 (alloy of tungsten + 5% rhenium paired with tungsten + 20% rhenium) is widely used, has a stable characteristic, and retains it after use at temperatures up to 1800°C. However, VR5/20 thermocouples can be used for a long time only in vacuum or inert media.

The work carried out in recent years by the department of high-melting-point materials of the Institute of Metal Ceramics and Special Alloys of the Academy of Sciences, Ukr.SSR has made it possible to produce thermocouples on the basis of high melting point compounds, such as borides, carbides, nitrides, and silicides of transition metals [2] for measuring temperatures of corrosive media and fused metals.

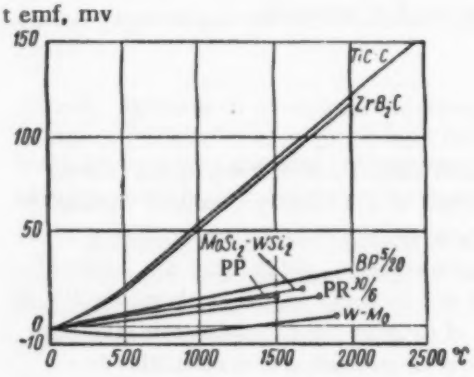

Fig. 1. Relation between thermal emf and temperature for the most common high-temperature metallic thermocouples and thermocouples made of high melting point compounds.

Such thermocouples are described in detail in [3] and structurally consist of a tube made of carbide, boride, nitride or silicide which serves simultaneously as a jacket and an electrode inside which a high-melting metal rod is placed concentrically and serves as a second electrode. The table shows the three basic types of thermocouples developed by the Institute of Metal Ceramics and Special Alloys of the Academy of Sciences Ukr.SSR.

Thermocouples made from high-melting compounds have a high thermal emf and a correspondingly high temperature sensitivity up to 75 μv/deg. It will be seen from Fig. 1 that the calibration curves of titanium-carbide against graphite and zirconium-boride against graphite thermocouples are close to each other, but tungsten-silicide and molybdenum thermocouples have a thermal emf approaching that of PP and PR30/6 thermocouples.

Titanium-carbide against graphite thermocouples are intended for measuring temperatures in vacuum, reducing (CO, H_2) and inert media; zirconium-boride against graphite thermocouples are intended for measuring temperatures of molten steel, cast iron, nonferrous metals and their alloys, and they can also be used for measuring temperatures in neutral media and vacuum. Finally, the molybdenum-disilicide against tungsten disilicide thermocouples are intended for measuring temperatures of oxidizing media.

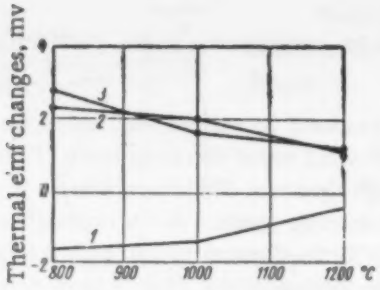

Fig. 2. Changes at various temperatures in the thermal-emf of TiC-C thermocouple after 25 hours operation in argon at a temperature of 2000-2200°C; 1,2, and 3 are thermocouples of the same batch of materials.

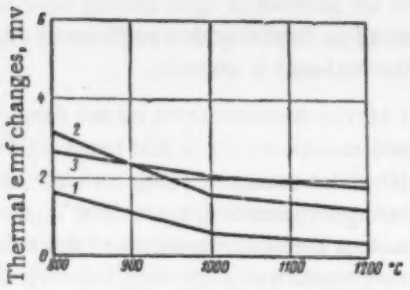

Fig. 3. Changes at various temperatures in the thermal-emf of TiC-C thermocouple; 1) after operation in hydrogen for 12 hr, thermocouple; 2) for 30 hr; and 3) for 45 hr at 2450°.

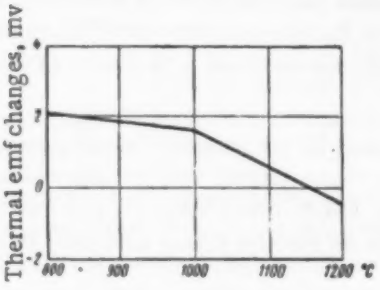

Fig. 4.

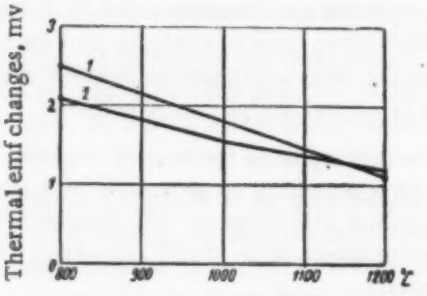

Fig. 5. Changes at different temperatures in the thermal-emfs of ZrB_2-C thermocouples after 25 hr operation in hydrogen at 1800-2000°C; thermocouples 1 and 2 are made from the same batch of material.

Preliminary tests of these high-melting-alloy thermocouples under commercial conditions have shown that they are suitable for measuring high temperatures under stringent conditions. Thus, thermocouple TiC–C has worked undamaged for more than 200 hr at a temperature of 2400°C in an electrical resistance furnace with a graphite heating tube (atmosphere of CO + N_2) without showing any appreciable changes in its readings. Zirconium-boride against graphite thermocouples withstand immersion in molten steel (open-hearth furnaces) at 1650-1700°C for several hours without any noticeable damage or variation in their calibration characteristics. These thermocouples can remain in molten cast iron at 1450-1500°C for many hours in a stationary condition without changing their electrical properties, and can withstand cast iron temperature variations in the trench during 20-25 discharges of the open-hearth furnace (i.e., 20-25 dippings). Since zirconium-boride, which forms the jacket of the thermocouple, remains extremely stable in molten cast iron and steel and is hardly wetted by them, the life of ZrB_2-C thermocouples may reach hundreds of hours. The high resistance of tungsten- and molybdenum-disilicide to oxidation amounting to several thousand hours [4], as well as the stability of graduation characteristics ascertained experimentally over 50 hr for thermocouples made of these alloys, provide good reasons to believe that the maximum life of such thermocouples in oxidizing media will amount to more than 1000 hr.

External electrode	Internal electrode	Thermocouple designation	Top measuring limit, °C
Titanium-carbide	Graphite	TiC–C	2500
Zirconium-boride		ZrB_2–C	2000
Molybdenum-disilicide	Tungsten-disilicide	$MoSi_2$–WSi_2	1650

For the purpose of studying the stability of high-melting-alloy thermocouples we tested titanium-carbide against graphite and zirconium-boride against graphite thermocouples. Thermocouples were first annealed for 2 hr at 2000-2200°C, and the calibrated and subjected to heating in periods of 10-15 hr at temperatures of 2000 and 2450°C in a graphite resistance furnace (Tammann furnace) in argon and hydrogen media; they were then withdrawn from the furnace and compared in argon with a reference platinorhodium-platinum thermocouples at temperatures up to 1200°C. Test results are shown in Figs. 2-5, from which it will be seen that the change in the thermal-emf of the titanium-carbide against graphite and zirconium-boride against graphite thermocouples after operation in argon and hydrogen media decrease with rising temperature, and their maximum error at 1200°C does not exceed 40°C.

Figure 4 shows changes in the calibration curve of a titanium-carbide against graphite thermocouple after 15 hr operation in hydrogen at 2450°C (this thermocouple was first annealed at the same temperature for 3 cycles, i.e., for about 30 hr). In this case the maximum error at 800°C did not exceed 30°C, and at 1200°C it did not exceed 7°C. Such a thermal-emf instability for a high-temperature thermocouple is permissible, since it does not vary at high temperatures. Thus, tests at 2400°C during 7 to 10 days have shown that changes in the emf of TiC−C thermocouples did not exceed 2 mv, i.e., 30°C (the temperature was checked by means of an optical pyrometer). The stabilizing annealing of high-melting alloy thermocouples improves their stability. Moreover, it should be noted that there is not a single high-temperature thermocouple described in literature which exceeds under the test conditions described the thermal emf stability of the high-melting-alloy thermocouples.

High-melting-alloy thermocouples made under standard conditions from chemically similar or identical powders have similar calibration characteristics, thus indicating the possibility of obtaining standard calibration curves.

Thermocouple inertia is one of their important characteristics. This characteristic was checked in ZrB_2-C thermocouples by measuring the temperature of steel in casting ladles.

For the abovementioned conditions the delay constant obtained by a controlled operation method for a zirconium-boride against graphite thermocouple with an external electrode 18 mm in diameter was found to be 78 sec, i.e. comparable to the delay constant of metal thermocouples with a medium thermal inertia.

In order to eliminate thermocouple errors due to the instability of the cold junction temperature, the thermal-emf of thermocouples was measured at 100°C. It was found to be equal to 2 mv, the same as that of chromel-copper thermcouples at 100°C. Therefore, chromel and copper wires can serve as compensation leads for titanium-carbide against graphite and zirconium-boride against graphite thermocouples.

SUMMARY

1. Thermocouples made of high-melting compounds of transition metals (carbides, borides, nitrides and silicides) make it possible to measure temperatures under more exacting conditions and have a higher thermal-emf than the existing metal high-temperature thermocouples; moreover, they are as accurate as metal thermocouples.

2. Changes in the thermal-emf of high-melting thermocouples decrease with a rising operation time, thus making it advisable and necessary to submit them to stabilizing annealing; by using thermocouple materials with close chemical tolerances, standardizing their production and annealing, it becomes possible to produce thermocouples with standard calibrations.

3. The results published in this article are not final, since they were obtained on several tens of thermocouples made under laboratory conditions.

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PRODUCTION AND ATTESTATION OF HIGHLY PURE ZINC

K. Ya. Bregman and N. P. Grudinkina

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pp. 23-24, May, 1961

In conducting the international comparison of the zinc solidification temperature for the purpose of replacing the sulfur reference point of the international temperature scale by a zinc reference point, it became necessary to develop methods for the production and attestation of highly pure zinc. The commercially produced zinc of a purity of 99.98-99.99% could only serve as an initial material for investigation.

The VNIIM (All-Union Scientific Research Institute of Metrology) Laboratory used electrolytic and vacuum distillation methods for purifying zinc. The zone-melting methods were not used owing to the large difference in the solidification temperatures of zinc and some of its admixtures (copper, iron).

It follows both from the data obtained in literature and our own experiments that electrolytic zinc purification under laboratory conditions provides a metal of the purity of 99.995-99.998%.

On the basis of the published data on vacuum distillation of metals and considering that in zinc there are admixtures with different physical properties, we decided to purify the zinc by distillation in vacuum with the selection of three fractions: the light, medium (basic) fraction, and the remainder.

For this purpose we constructed a special vacuum equipment. The distillation was carried out in flasks made of 3S-5 glass with a melting temperature 585-590°C. Weighed samples of zinc grains (400 g) were placed in the flask and the open end of the tube sealed. The sealed flasks with the zinc samples were placed in an oven and the outlet tube of the flask sealed to a special connecting strip which led to the prevacuum pump. The zinc was purified in the following manner. By heating up the oven slowly its temperature was raised to 460°C, and at this temperature distillation of the first fraction was carried out for 4 hr. The distillation of the middle fraction was carried out at a temperature of 485°C for 6.5 hr. The middle fraction obtained from the first sublimation served to start the second sublimation. The withdrawn middle fraction amounts to 50%. The first and third fractions were discarded.

TABLE 1

Zinc fraction	Impurities, %				
	cadmium	lead	iron	tin	copper
Middle fraction of the first sublimation	0.0005	0.0006	–	–	0.00003
Middle fraction of the second sublimation	–	–	–	–	0.000002
Middle fraction of the third sublimation	–	–	–	–	0.000001
Zinc (USA)	0.00005	0.0001	0.0004	0.00005	0.00005
" " SP	0.00005	0.0002	–	–	Traces

The attestation of zinc was carried out by an emission spectral analysis method. The main difficulty in analyzing zinc for small impurities consists in the fact that in the burning process a large amount of oxide is produced which tends to heat up considerably the electrodes and form a continuous spectrum, thus reducing the sensitivity of the method. There are descriptions in literature of methods and sources especially used for analyzing zinc, but none of them provide the possibility of attesting highly pure zinc. It was therefore decided in attesting the zinc obtained by us to prepare samples enriched with impurities.

For this purpose we used zinc fractions obtained in the purification process. The middle fraction depleted of admixtures was the purest of all.

An ac arc without an interrupter was used as a source of excitation. Zinc rods 8-10 mm in diameter served as electrodes. With such a shape of electrodes the most constant background was obtained on the spectrogram. This background served as an internal standard for quantitative measurements of impurities in zinc, since the zinc spectrum itself has only a few lines suitable for comparison purposes.

The results of the spectral analysis are given in Table 1. The total relative error of measurement is ±40%. For comparison purposes Table 1 contains the percentage content of impurities according to the certificate supplied with two zinc samples which we obtained from Canada. It will be seen from Table 1 that in the third sublimation with a 40-fold enrichment even traces of the four tested elements cannot be found, whereas in the sample send from Canada even without any enrichment we found two copper and one cadmium line.

TABLE 2

cadmium	lead	iron	tin	copper	Total content of impurities, %
0.00001	0.00002	0.00002	0.000002	0.000001	0.000053

Considering the sensitivity of the spectral analysis method and assuming that in a 40-fold enrichment the content of impurities in the composition also increases 40-fold, it can be assumed that the middle fraction of the third sublimation has impurities which do not exceed the values given in Table 2. Thus, a purity of zinc of the middle fraction of the third sublimation amounts to 99.99995%.

The zinc thus obtained was cast a graphite mold in the form of 8-9 mm rods, and an amount of 4 kg was sent to the International Bureau of Weights and Measures for their work in the international comparison of the solidification temperatures of zinc.

The National Scientific Research Council in Ottawa tested the solidification temperatures of eight zinc samples sent to them from four countries (USSR, USA, Canada and Britain) and found that the Soviet samples had an extremely stable solidification temperature, which undoubtedly indicates their high degree of purity.

In [1] the data obtained from the testing of the above samples are given. The investigation of two Soviet zinc samples and their comparison with the reference zinc standard of the highest purity SP (USA) is described in particular detail.

The analysis of the solidification and fusion curves obtained for various conditions indicates convincingly the undoubted superiority of the Soviet samples above all the others.

Thus, the Soviet zinc purified by the VNIIM can be considered the best in the world. Its purity was obtained by the correct selection of the purification method, the operating conditions and the observation of maximum sterilization during operations.

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GENERALIZED METHODS OF COMPUTING MUTUAL AND INPUT ADMITTANCES OF SINGLE BRIDGE CIRCUITS

V. G. Pustynnikov

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This article deals with two general methods of computing mutual and input impedances of bridge circuits, one of which is partly described in [1].

First method. Let us use a circuit (Fig. 1a) in which the letters have a dual significance: a) as designation of branches, b) as designation of impedances in terms of the Z_g impedance of the variable arm:

$$g=1; \quad b=\frac{Z_b}{Z_g}; \quad n=\frac{Z_n}{Z_g}; \quad m=\frac{Z_m}{Z_g};$$
$$p=\frac{Z_p}{Z_g}; \quad k=\frac{Z_k}{Z_g}. \tag{1}$$

Let us draw an equivalent circuit (Fig. 1b) from which we can find the input admittance looking at branch g:

$$Y_{gg}=Y_{gp}+Y_{gk}, \tag{2}$$

where Y_{gp} and Y_{gk} are the mutual admittances between branches p and k and branch g respectively. Let us redraw the circuit (Fig. 1a) in the form of a design diagram (Fig. 2) by converting into a star the triangle formed by the sides n, m and b. The design values

$$n'=\frac{nb}{n+m+b}; \quad m'=n'k; \quad p'=p+n'\frac{m}{b} \tag{3}$$

form the rays of the star equivalent to the above-mentioned triangle.

Let us represent the design bridge circuit in the form of an equivalent passive quadrupole (Fig. 3) which is determined by two equations [2]:

$$\Delta\dot{U}_g=A\Delta\dot{U}_p+B\Delta\dot{I}_p; \tag{4}$$
$$\Delta\dot{I}_g=C\Delta\dot{U}_p+D\Delta\dot{I}_p \tag{5}$$

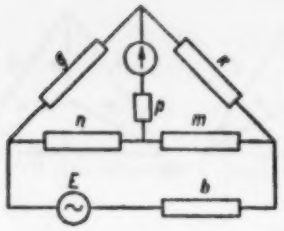
with its output across impedance p. In this circuit the input voltage is represented by the voltage drop

$$\Delta\dot{U}_g=\dot{U}_{0g}\frac{Y_{gg}\Delta Z_g}{1+Y_{gg}\Delta Z_g} \tag{6}$$

across impedance ΔZ_g. This voltage is determined according to Thevenin's theorem. Here U_{0g} is the voltage across the terminals of the variable branch Z_g for $\Delta Z_g=\infty$; $\Delta\dot{U}_g$, $\Delta\dot{U}_p$, $\Delta\dot{I}_p$ and $\Delta\dot{I}_g$ are the input and output voltages and currents respectively; A, B, C and D are the quadripole coefficients which can be expressed by means of one design quantity

$$n'=A=1+BC; \quad C=\frac{1}{KB}; \quad B=1+n'; \quad D=1. \tag{7}$$

On the basis of the above it is possible to write design formulas for the input impedance:



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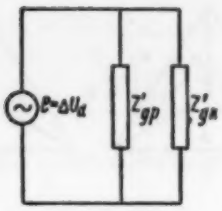

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Fig. 1.

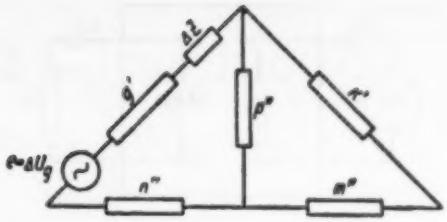

Fig. 2.

$$Y_{gg}=\frac{CZ_p+D}{AZ_p+D},\quad \text{or}\quad Y_{gg}=\frac{Cp'+1}{Ap'+B} \tag{8}$$

and the mutual admittances of the bridge circuit looking at the variable arm g:

$$Y_{gp}=\frac{1}{Ap'+B}; \tag{9}$$

$$Y_{gk}=\frac{Cp'}{Ap'+B}. \tag{10}$$

In order to determine the mutual admittances

$$Y_{gn}=\frac{\Delta \dot{I}_n}{\Delta \dot{U}_g};\quad Y_{gb}=\frac{\Delta \dot{I}_g}{\Delta \dot{U}_g};$$

$$Y_{gm}=\frac{\Delta \dot{I}_m}{\Delta \dot{U}_g} \tag{11}$$

between the variable arm g and the arms n, b and m it is necessary to insert in (11) the expressions for current increments

$$\Delta \dot{I}_n=\frac{\Delta \dot{I}_g b+\Delta \dot{I}_p m}{n+m+b};$$

$$\Delta \dot{I}_b=\frac{\Delta \dot{I}_g n+\Delta \dot{I}_k m}{n+m+b};$$

$$\Delta \dot{I}_m=\frac{\Delta \dot{I}_k b-\Delta \dot{I}_p n}{n+m+b} \tag{12}$$

in the sides of triangle n, m and b, which was previously converted into an equivalent star, also taking into consideration (5), (6) and (7). In this case we shall finally obtain:

$$Y_{gn}=\frac{1}{Ap'+B}\cdot\frac{Cp'b+b+m}{n+m+b}; \tag{13}$$

$$Y_{gb}=\frac{1}{Ap'+B}\cdot\frac{Cp'(n+m)+n}{n+m+b}; \tag{14}$$

$$Y_{gm}=\frac{1}{Ap'+B}\cdot\frac{bCp'-n}{n+m+b}. \tag{15}$$

Expression $1/(A_{p'}+B)$ does not depend on the value of the internal impedance b of the source of energy, and hence can be found from a simpler circuit for the case when $b=\infty$ or for the case when $b=0$.

Second method. For the calculation of the input and mutual admittances of the bridge looking from the side of arm g we have obtained equations (3), (7-10), (13-15) with the equivalent quadrupole coefficients forming a matrix

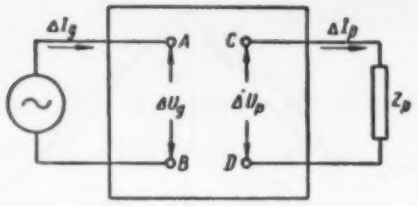

Fig. 3.

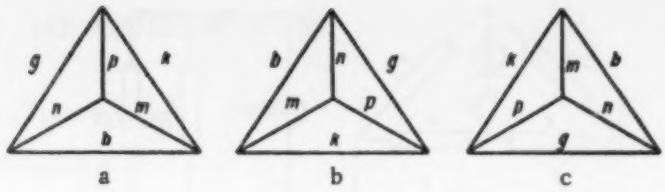

Fig. 4.

$$M_{gp}=\left\| \begin{matrix} A_{gp} & B_{gp} \\ C_{gp} & D_{gp} \end{matrix} \right\|. \tag{16}$$

Here subscript gp indicates that coefficients A_{gp}, B_{gp}, C_{gp} and D_{gp} are quadrupole parameters of the equivalent bridge circuit whose input is obtained by looking at arm g, and the output is connected to diagonal p (Fig. 3).

Should it be necessary to calculate the input or mutual admittance of the circuit from any other side of the bridge, for instance, Y_{bb}, Y_{bn}, Y_{bk}, etc. looking at branch b (Fig. 4b), or Y_{kk}, Y_{kp}, Y_{kn}, etc. looking at branch k (Fig. 4c), it is obviously necessary to transform the above circuit every time into a design diagram and then an equivalent quadrupole. In the first case the input of the quadrupole will be obtained by looking at branch b and the output across branch n. The coefficients of such a quadrupole will form a matrix

$$M_{bn}=\left\| \begin{matrix} A_{bn} & B_{bn} \\ C_{bn} & D_{on} \end{matrix} \right\|. \tag{17}$$

In the second case the quadrupole coefficients will form another matrix

$$M_{km}=\left\| \begin{matrix} A_{km} & B_{km} \\ C_{km} & D_{km} \end{matrix} \right\|. \tag{18}$$

In order to reduce the number of the above-mentioned transformations to one it is possible to utilize (3-8), (11-13) and the peculiarity of the circuit, to preserve the properties of the bridge; i.e. to represent a star (Fig. 4a) inscribed into a triangle, irrespective of the change in the purpose for which any of the branches are used; for instance, irrespective of the transfer of the current source from one part of the circuit to another, etc. This makes it possible to divide all the mutual admittances of the circuit into two typical groups. The first group comprises admittances Y_{bp}, Y_{gm} and Y_{km}, which we shall henceforth call mutual admittances of diagonal couplings. They can be analyzed by means of (13). For instance, the mutual conductance between branch b and branch n is determined from

$$Y_{bn}=\frac{1}{Ap'+B}\cdot\frac{bCp'-n}{n+m+b}. \tag{19}$$

All the remaining mutual admittances (with the exception of the three diagonal ones), for instance, Y_{gp}, Y_{gk}, Y_{gb}, etc. comprise the second group, and they are also computed by means of (19), providing

$$\frac{bCp'-n}{n+b+m}=1. \tag{20}$$

Example 1. Calculate the mutual and input admittances of a bridge circuit with impedances $Z_g=Z_k=Z_b=Z_p=200$ ohm and $Z_n=Z_m=100$ ohm.

Let us first determine:

a) the impedances of the circuit components in relative units $g=k=b=p=1$ and $n=m=0.5$;

b) the design quantities of the bridge from (3)

$$n'=\frac{nb}{n+m+b}=\frac{0.5\cdot 1}{0.5+0.5+1}=0.25;$$

$$p'=p+n'\frac{m}{b}=1+0.25\frac{0.5}{1}=1.125;$$

c) the equivalent quadrupole coefficients from (7):

$$D=1;\quad B=1+n'=1+0.25=1.25;$$

$$C=\frac{1}{kB}=\frac{1}{1\cdot 1.25}=0.8;$$

$$A=1+BC=1+1.25\cdot 0.8=2.$$

Let us now find from (8) the input admittance looking at branch g:

$$Y_{gg}=\frac{Cp'+1}{Ap'+B}=\frac{0.8\cdot 1.125+1}{2\cdot 1.125+1.25}=0.543.$$

From (9), (10), (13), (14) and (15) let us calculate the mutual admittances between branches p, k, n, b and m and branch g respectively:

$$Y_{gp}=\frac{1}{Ap'+B}=\frac{1}{2\cdot 1.125+1.25}=0.286;$$

$$Y_{gk}=\frac{1}{Ap'+B}\,Cp'=0.286\cdot 0.8\cdot 1.125=0.257;$$

$$Y_{gn}=\frac{1}{Ap'+B}\cdot\frac{Cp'b+b+m}{n+m+b}=$$

$$=0.286\,\frac{0.8\cdot 1.25\cdot 1+1+0.5}{0.5+0.5+1}=0.343;$$

$$Y_{gb}=\frac{1}{Ap'+B}\cdot\frac{Cp'(n+m)+n}{n+m+b}=$$

$$=0.286\,\frac{0.8\cdot 1.125\,(0.5+1.05)}{0.5+0.5+1}=0.2;$$

$$Y_{gm}=\frac{1}{Ap'+B}\cdot\frac{bCp'-n}{n+m+b}=$$

$$=0.286\,\frac{1\cdot 0.8\cdot 1.125-0.5}{0.5+0.5+1}=0.0572.$$

$$\frac{\partial i_p}{\partial Z_g}:\frac{\partial i_k}{\partial Z_g}:\frac{\partial i_g}{\partial Z_g}:\frac{\partial i_n}{\partial Z_g}:\frac{\partial i_b}{\partial Z_g}:\frac{\partial i_m}{\partial Z_g}=1:Cp':(1+Cp'):$$

Example 3. Find the conditions for which the bridge circuit given in 1 will be balanced along three diagonal couplings. By definition in this circuit $Y_{bp}=0$, hence gm = kn or m = kn.

It will be seen from (15) that the given bridge balances simultaneously along the diagonal coupling gm providing

$$bCp'-n=0.$$

Taking into consideration (3) and (7) we have

$$b\left(p+\frac{nm}{n+m+b}\right)=nk\left(1+\frac{nb}{n+m+b}\right).$$

Considering that m = kn we find that $Y_{gm}=0$ providing bp = m.

A bridge circuit balanced along three diagonal couplings has a number of important properties of practical value.

Example 4. In order to illustrate the application of the second method for computing impedances let us show how to find formulas for a calculation of mutual and input admittances which comprise the current equation of the measurement diagonal of the bridge, whose two arms g and k change their impedance values simultaneously.

For checking the computation:

$$Y_{gg}=Y_{gp}+Y_{gk}, \quad \text{or} \quad 0.543=0.286+0.257.$$
$$Y_{gk}=Y_{gb}+Y_{gm}, \quad \text{or} \quad 0.257=0.2+0.0572.$$

Example 2. Show the relationship between the current sensitivities of separate elements of the bridge circuit given in example 1 and the resistance of the variable arm.

It is known that the relation of the current sensitivity of any bridge arm, for instance, p, to the impedance of arm g can be represented according to [3] by the equation:

$$S_{gp}=-I'_g Y_{gp}\left(\frac{1}{1+Y_{gg}\Delta Z_g}\right)^2.$$

From the above we can write:

$$\frac{\partial I'_p}{\partial Z_g} : \frac{\partial I'_k}{\partial Z_g} : \frac{\partial I'_g}{\partial Z_g} : \frac{\partial I'_n}{\partial Z_g} : \frac{\partial I'_b}{\partial Z_g} : \frac{\partial I'_m}{\partial Z_g} = Y_{gp} : Y_{gk} : Y_{gg} : Y_{gn} : Y_{gb} : Y_{gm}.$$

Using equations (9), (10), (8), (13), (14) and (15) we can obtain coefficients which show the ratio of the relation between sensitivity of a given branch of the circuit and the impedance to the relation between the sensitivity of the measurement diagonal p and the same impedance Z_g, i.e.

$$\frac{b(Cp'+1)+m}{n+m+b} : \frac{n(Cp'+1)+Cp'm}{n+m+b} : \frac{bCp'-n}{n+m+b}.$$

The equation for the measurement diagonal current

$$\Delta I'_p=I'_g[Y_{gp}\Delta Z_g+(Y_{gp}Y_{hk}-Y_{gk}Y_{hp})\Delta Z_g\Delta Z_k]:\xi+I'_k[Y_{hp}\Delta Z_k+(Y_{gg}Y_{hp}-Y_{gk}Y_{gp})\Delta Z_g\Delta Z_k]:\xi$$

has been taken from [4] and rewritten for the bridge circuit (Fig. 1a). Here $\xi = 1+Y_{gg}\Delta Z_g+Y_{kk}\Delta Z_k+(Y_{gg}Y_{kk}-Y_{gk}^2)\cdot\Delta Z_g\Delta Z_k$. Admittances Y_{gg}, Y_{gp} and Y_{gk} are found from matrix (16) by means of formulas (8), (9) and (10). The values of admittances Y_{kk} and Y_{kp} are also found from (8) and (9) by inserting into them coefficients which form matrix (18) and are determined from, as it were, a new bridge circuit (Fig. 4c), in which branches b, p, g, m, k and n are substituted by branches g, m, k, n, b and p respectively.

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DC BRIDGE TYPE R316

A. F. Gorodovskii and V. P. Kotel'nikov

Translated from Izmeritel'naya Tekhnika, No. 5,
pp. 28-31, May, 1961

The possibility of measuring resistances over a wide range by means of bridges with an error of 0.2-0.5% is important from the practical point of view. The single bridge type R316 attains to a considerable extent this objective. Bridge R316 is intended for measuring dc resistors in the range of 10^{-5} to 10^{6} ohm. Its basic characteristics are given in the table and compared with other measuring bridges.

Bridge designation	Measuring range, ohm	Measurement error, %	Over-all dimensions, mm	Weight, kg	Supply source characteristics	
					internal	external
R333	$1-10^{4}$ $0.1-1$ $0.005-0.1$ $10^{5}-10^{6}$	± 0.5 ± 1.5 ± 5 ± 5	300×230×150		5 "Saturn" elements	20 v
UMV	$1-10^{5}$ $10^{5}-10^{6}$	± 0.5 ± 5	270×230×160	4.7	–	2–20 v
MKMV	$1-10^{7}$	± 0.1	370×300×195	10	4.5 v	24 v for $R_x > 10^{4}$ ohm
MVU-49	$10-10^{5}$	± 0.1	270×226×177	5.5	4.5 v	When measuring large resistances
MD6	$10^{-5}-10^{-4}$ $10^{-4}-11$	$\pm 2-20$ $\pm 1-10$	360×205×175	5	–	1.2 v (0.003–20 amp
M246	10^{-4} $10^{-3}-1$	$\pm 3.5\%$ fsd $\pm 2\%$ fsd	350×280×170	18	ac mains	0.1–20 amp
Doran Company (Britain)	$10^{-3}-10^{7}$	± 0.1	300×250×200	6	–	–
Pye Company (Britain)	$10^{-4}-10^{5}$	± 0.02	–	–	–	–
R316	$10^{-5}-10^{-3}$ $10^{-3}-10^{5}$ $10^{5}-10^{6}$	$\pm 5^{*}$ ± 0.2 $\pm 5^{*}$	300×230×150	6	ac mains ($I_{max} = 1.5$ amp)	Facilities for an external dc supply

* The error amounting to 5% in these ranges is due to a reduced sensitivity of the circuit and the use of a non-wire-wound resistor (10^{5} ohm) in the ratio arms.

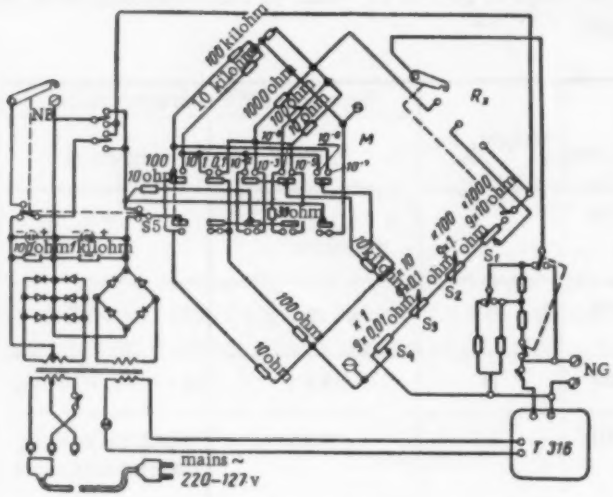
It will be seen from the Table that bridge R316 as compared with other bridges has the following advantages: a much larger range; smaller errors in measuring small resistances; small power consumption, amounting to 1.5 amp when measuring low-value resistances; and a small size and weight.

These advantages have been attained owing to the rational selection of the bridge circuit and the use of a highly sensitive T316 null-indicator. The schematic of bridge R316 is given in Fig. 1. The same figure shows the methods of connecting the measured resistance. The low-value resistances are measured in a four-terminal circuit.

The four-terminal connection of the measured resistances in the single bridge circuit decreases considerably the effect of conductors and contact resistances as compared with a two-terminal connection.

In order to obtain sufficient sensitivity in measuring low-value resistances, the variable arm of the R316 bridge is made of a low resistance of 100 ohm; the smallest decade of the arm consists of ten steps of 0.01 ohm; the zero resistance is incorporated in the first step of the smallest decade and its readings do not start with zero but with unity. In order to decrease the effect of the switch contact resistances on the readings of the variable arm, it is connected in a three-terminal circuit, thus making it possible to eliminate the contact resistance of one of the switches (S_4) by connecting it in series with one of the relatively high resistance ratio arms. As a result of this the effect of only one contact resistance of a switch and its variations have been made negligibly small.

The bridge circuit is improved still further by measuring high-value resistors in a two-terminal circuit. In this case the highest variable arm decade is also connected in a three-terminal circuit, thus providing a relative constancy of the input (on the supply side) resistance; when the measuring arm is varied from its maximum to its zero value the input resistance of the bridge only changes by 10%. This eliminates overheating of the measuring resistors at the top limit of the range of 10^5-10^6 ohm in which a higher supply voltage is used.



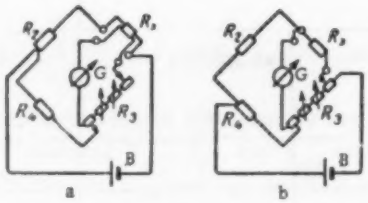


Fig. 1. a) Four-terminal method of connecting the measured resistance; b) Two-terminal method of connecting the measured resistance.

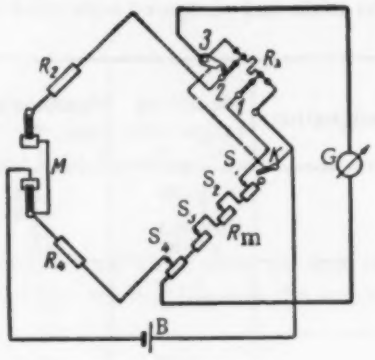


Fig. 2.

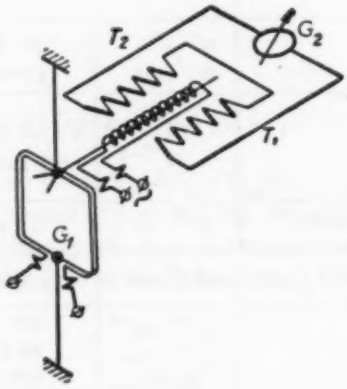


Fig. 3.

The switching of the ratio arms is made by means of a double wiper switch M in a three-terminal circuit, so that the contact resistance of one wiper is included in the battery circuit and of the other in the circuit of the high-value (at least 1000 ohm) resistor. The effect of the contact resistances of this switch is obviously negligible.

The above peculiarities of the measuring bridge circuit are illustrated in Fig. 2. In measuring high-value resistors (over 20 ohm) terminals 2 and 3 are shorted by a link and push-button K is operated at the same time. The measured resistance is connected to the two terminal circuit to terminals 1 and 2.

Indicator T316 consists of a galvanometric amplifier. The schematic of the indicator is shown in Fig. 3.

The galvanometer moving coil G_1 is fixed to a hollow glass pointer with external and internal diameters of 0.35 mm and 0.15 mm respectively, and a length of 40 mm. The pointer is wound with a 600 ohms spiral heater of

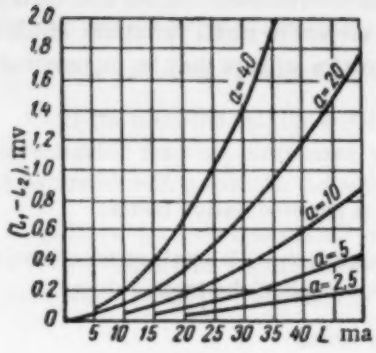


Fig. 4.

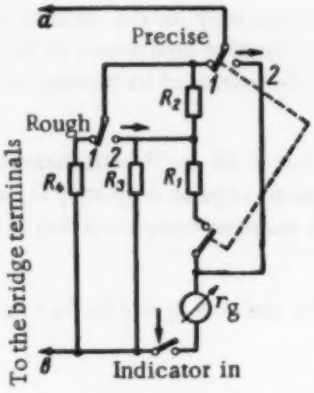


Fig. 5.

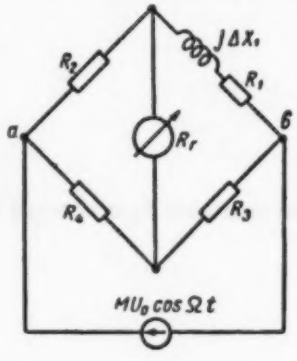


Fig. 6.

0.025 mm bare nichrome wire. The spiral is connected by means of light-weight conductors to an ac current (31 ma) supply, which establishes on the surface of the surface of the heater a temperature of 170°C.

On either side of the heater two thermopiles of 20 thermocouples each are connected in series opposing. The thermocouples' cold junctions are placed under relatively massive metallic plates. The thermocouples consist of manganin-constantan 0.05 mm conductors with an effective length of 1.8-2 mm.

Figure 4 shows the relation of the thermal-emf at the output of the thermopile (E_1-E_2) to the current i following through the heater for various deviations a (in microns) of the heater from the thermal equilibrium position.

The principle of operation of the indicator consists of the following. In the absence of a current through the input galvanometer G_1 the heater is set by means of a corrector into a position symmetrical with respect to the thermopiles T_1 and T_2.

The output galvanometer G_2 is then under the effect of two equal and opposite thermal-emfs E_1 and E_2, and there is no current flowing through it. As soon as a current flows through galvanometer G_1 its moving system together with the heater deflects, the thermal-emf of one thermopile increases and that of the other decreases. Then, under the effect of the difference of the thermal-emfs the moving coil of galvanometer G_2 is deflected.

Structurally the indicator is made in the form of a separate instrument with a common magnetic circuit for both galvanometer moving coils. The electrical parameters of the indicator are: the current sensitivity $C_i = 1 \cdot 10^{-7}$ amp/div, input resistance $r_g = 4$ ohm, its reading setting time amounts to 4 sec when galvanometer G_1 is connected to an external resistance of at least 10 ohm, the gain of the indicator amplifier is

$$K = \frac{\alpha_2}{\alpha_1} = 200,$$

where α_2 and α_1 are the angular deflections of the output and input galvanometer moving coils.

The method of connecting the indicator to the measuring diagonal of the bridge is shown in Fig. 5. For adjusting the sensitivity of the indicator three push-buttons are used: "Indicator in," "Rough," and "Precise."

When the first button is depressed the indicator sensitivity is only 1/400 of its maximum. The push-button "Rough" (position 2) raises its sensitivity to 1/20 of the maximum. When button "Precise" (position 2) is depressed its sensitivity is maximum.

In the initial position the push-button "Indicator in" disconnects the indicator circuit, with the other two buttons in position 1.

Such a three-step control of the indicator sensitivity is possible when

$$R_1 = R_2 = 19\, r_g,$$

$$R_3 = R_4 = \frac{20}{19} r_g,$$

where r_g is the indicator input resistance. Moreover, it can easily be shown that the resistance of the indicator sensitivity control circuit seen from terminals ab is constant and equal to r_g. Thus, with the consecutive operation of the three push-buttons the bridge circuit sensitivity with respect to current remains constant.

The R316 bridge circuit is fed from ac mains through a rectifier. Besides its convenience this has also certain disadvantages. Experience has shown that the amplitude of the supply voltage is subject to small variations which are of the nature of a random stationary process. In a very rough approximation the mains voltage may be represented in the form of modulated oscillations.

$$u = U_{\max}[1 + M\cos\Omega t]\cos\omega t,$$

where ω is the mains angular velocity; Ω is the modulation angular velocity; M is the modulation factor.

The time constant of the rectifier load (filter and the resistance of the bridge circuit) is small as compared with the period of the modulating frequency, and the rectified voltage varies as the envelope of the input voltage.

The mean value over a period of the rectified voltage is thus a function of time.

$$u_0(t) = U_0[1 - M\cos\Omega t].$$

If the measured impedance has a reactive component, the bridge will be balanced only for the constant component of the rectified voltage; hence, after the bridge is balanced with respect to the resistive component of the measured impedance a current of frequency Ω will flow through the indicator. Owing to the inertia of its moving coil system the indicator will not react to the pulsations of the rectified voltage.

The current of frequency Ω, which according to our experience is equal to 0.628-6.28 $\sec^{-1}$, will make the indicator pointer oscillate at this frequency. Let us find the value of the current with an angular frequency Ω, which flows through the indicator when an impedance with a resistive component R_1 and a reactive component Δx_1 is measured, by the method of a fictitious emf (Fig. 6).

We consider the bride to be almost balanced and neglect the shunting effect of resistors R_2 and R_4 ($R_2 + R_4 \gg R_g$). Then:

$$I_\Omega = \frac{MU_0\cos\Omega t\,\Delta x_1}{(R_4 + R_3)(R_1 + j\Delta x_1 + R_2 + R_3)}.$$

By neglecting $j\Delta x_1$ in the denominator and expressing Δx_1 in terms of the measured resistance time constant $\Delta x_1 = R_1\Omega\tau_1$, we obtain

$$I_\Omega = \frac{MU_0\Omega\tau_1\cos\Omega t}{\left(1 + \frac{R_2}{R_1}\right)(R_1 + R_2 + R_3)} = I_{m\Omega}\cos\Omega t. \qquad (1)$$

The value of the direct current flowing through the indicator when the measured resistance R_1 is changed by ΔR_1 found by means of the same method is equal to

$$I_{z0} = \frac{U_0\xi}{\left(1 + \frac{R_2}{R_1}\right)(R_1 + R_2 + R_3)}, \quad \text{where} \quad \xi = \frac{\Delta R_1}{R_1}. \qquad (2)$$

From (1) and (2) we find

$$K = \frac{I_{m\Omega}}{I_{z0}} = \frac{M\Omega\tau_1}{\xi} \quad \text{or} \quad \tau_1 = \frac{K\xi}{M\Omega}.$$

For a reliable measurement of resistor R_1 which has a reactive component Δx_1 it is necessary, apparently, to make $K \leq 0.1$. From experimental data we know that $M = 0.01$ and $\Omega = 6.28\ \sec^{-1}$.

By inserting these values into the formula we have

$$\tau_1 = 1{,}5\xi \qquad (3)$$

In measuring resistances in the working range of 10^{-2} to 10^{5} ohm the measurment error ξ is equal to 0.2% and the permissible value of the time constant is $\tau_1 \leq 0.003$ sec.

The values of τ_1 valculated from (3) are in good agreement with experimental data.

If the rectified voltage supplied to the bridge is not sufficiently filtered and if the measured impedance has a considerable reactive component, a large ac unbalanced current will flow through the zero indicator when the bridge is balanced with respect to the active component of the impedance.

Since the indicator circuit consists of various types of materials (copper, bronze, tin, manganin) the existence in it of a neglibible "microrectifying" effect must be assumed. This circumstance makes the indicator pointer oscillate about a point on the indicator scale which does not coincide with zero.

RESISTANCE BOX FOR CALIBRATING AND CHECKING MEGOHMMETERS

N. N. Kalashnikov

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Repair workshops and area test laboratories are badly in need of resistance boxes for testing megohmmeters.

The "Uzbekorgenergo" laboratory produced at the end of 1959 a resistance box (based on R-14) for checking megohmmeters with a range of 0.001 to 111.111 meg.

Resistors for the lowest ranges (from 1 to 40 kilohm) were taken partly from resistance box R-14 and the remaining were made up with MLT-2 resistors. The maximum nominal value of these resistors is equal to 8.2 meg. Their actual resistance was measured on bridge MKMV with an external battery and galvanometer. After the actual values of the resistors were determined they were made up into sets corresponding to the nominal values of the resistance box. Any value in steps of 1 kilohm can be obtained on the box by means of plugs. This is very convenient in calibrating megohmmeters, since it provides any resistance value even for unmarked parts of the scale.

In making the box, all the laminas were smoothed out with a file (their edges were rounded), and the distance between them was increased in order to eliminate the possibility of a break-down. As a result of this even MS-60 (2500 v) megohmmeters can be checked on this box without causing a breakdown between laminas.

The resitance box was tested in 1960 at the Tashkent GKL (State Inspection Laboratory) on a UPMS-1 equipment. It was found that the largest relative error of any step on the resistance box did not exceed + 0.53 to -0.56%, and the maximum total error did not exceed ± 0.5%.

When the resistance box was checked a second time after six months' use the relative errors of separate steps changed, owing to the variation in the value of the resistors, to+ 0.52 to -0.23%, and the total maximum errors to +0.38 to -0.2%.

The box weighs only 3.5 kg and has small dimensions of 260·190·135 mm.

CLASSIFICATION OF DIGITAL MEASURING INSTRUMENTS

M. P. Tsapenko

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Digital measuring instruments (DMI) have been known for a long time, but recently their use has increased considerably. At present they solve many measurement problems, and the automatic digital instruments make it possible to raise the speed and accuracy of many measurements, they form the basic elements of centralized automatic control systems and are used as input devices in electronic control machines.

The classification of some digital instruments and coding devices which convert analogue quantities into a digital form and constitute an essential part of the above instruments has been dealt with in many papers [8, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 and others]. However, it can be asserted that there is no established classification for coding devices and digital instruments. At the same time, it would appear, there is undoubtedly a pressing need for such classification.

We examine below the problems of such classification on the basis of the well-known definition that "measurement is a cognition process which consists of comparing in a physical experiment a given quantity with its value taken for a unit of measurement."[3] It follows from this definition that whatever conversions a measured quantity may be subjected to, it is always compared in measurements with a known value. It is understood that the known value can be compared experimentally either to the measured quantity or to a quantity which determines it.

The measurement result is normally represented in the form of a numerical equivalent of the measured quantity [2]. In order to obtain this equivalent from analogue instruments the operator must express the value of the analogue output quantity in the form of a digital code. In digital instruments this process forms the basis of its operation.

Henceforth we shall consider as digital those instruments which perform quantization (if necessary) and digital coding of the measured quantity, and present the measurement results in a digital form. By level quantization we understand the rounding off [10] of an analogue quantity to its nearest discrete value consisting of the sum of a whole number of quanta; and by time quantization the obtaining of values of the analogue quantity at given time intervals.

By digital coding we understand the process of obtaining the numerical equivalent of an unknown quantity, and by a digitizer a device by means of which digital coding is obtained.

Measuring instruments may compare the measured quantities with their known values either of a discrete or analogue nature. Constant value measures, samples and sample substances, as well as devices for transferring their values, may be considered as known discrete quantities. Known analogue values and devices which serve to transfer their values.

Typical devices which serve to transfer the value of a measure consist of spiral springs connected to pointer indicating devices and widely used in electrical measuring instruments. Known discrete quantities may be single-values or presented in the form of sets or boxes of known quantities. Their values may be expressed in a given code.

It should be noted that whereas in analogue measuring instruments known variable quantities (AQ) are used for comparison with measured analogue quanties (AQ_X), in digital measuring instruments known discrete quantities (DQ) are used for measuring both analogue (AQ_X) and discrete (DQ_X) quantities (henceforth unknown measured quantities we shall denote by Q_X and known quantities by Q).

From the above definition of digital instruments we can conclude that they should consist of a digitizer and an output (readout) device (it is assumed that quantization of the measured analogue quantity is made in the digitizer and therefore no separate component is assigned for quantization).

In addition to the digitizer and the output device, the digital instruments may contain converters of the measured analogue quantity into intermediate analogue quantities. Such converters can be used in digital instruments, for instance, in the case when intermediate analogue quantities are easier to convert into a digital code than the measured quantity.

Intermediate converters may consist of measuring instruments, instruments without indicating devices, as well as functional converters. In the latter the measured analogue quantities are expressed in intermediate values by means of known functional relations between them, so that each analogue quantity may be expressed by different intermediate values.

Thus, we propose to distinguish between digital instruments which contain intermediate converters and those which do not contain them.

Classification of measuring methods used in digitizers. Digital instruments, probably the same as any other measuring instruments, can be divided by their method of comparing the measured with the reference quantities into those using simultaneous or consecutive comparison methods [2,4].

Let us examine the method of measuring used in digital instruments and the measurement techniques on which it is based.

Methods of measuring. (Fig. 1). It is possible to compare the unknown with the known quantities by two methods. In the first method the discrete quantity is varied until it balances with the unknown quantity, or until their effects are balanced (here under balancing we understand the closest possible approximation of the two quantities to a state of balance). Let us call this method balancing of the measured quantity. In the other method the value of the discrete quantity built up according to a given code does not vary during the comparison, and the unknown quantity is compu-

ted from the value of the discrete quantity which coincided with it. Let us denote this as the method of coincidence between the unknown and known quantities. It should be noted that this term was used [3,5] for denoting a method in which a series of uniformly alternating marks or signals of the unknown quantity are compared with a series of known marks or signals. It appears to us that the concept of coincidence between the unknown and known quantities clearly assumes that the known quantity does not vary during comparison.

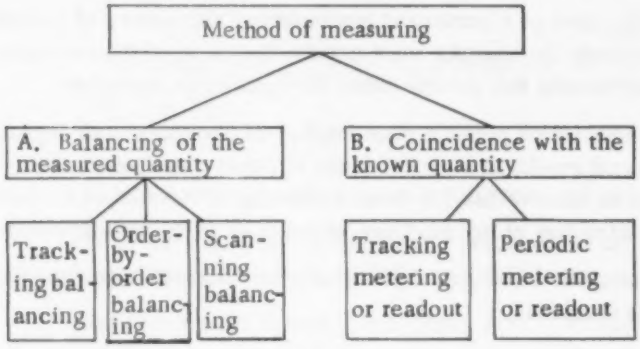

Fig. 1.

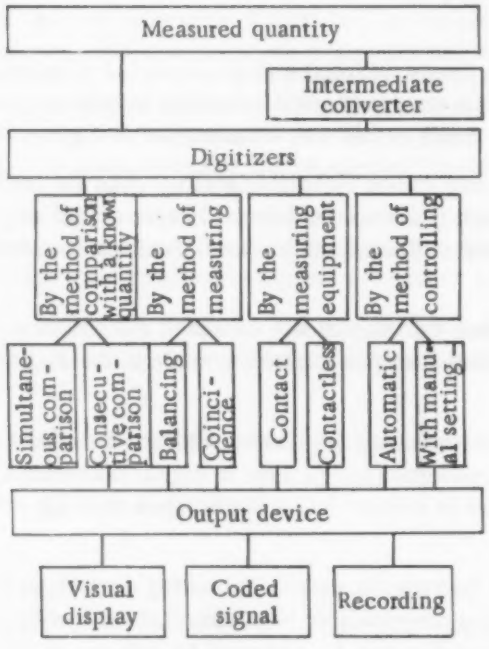

Fig. 2.

The discrete quantity can be changed or made up according to different codes. If the discrete quantity is built up on a unit code basis (a code with unity as its base) it is possible to provide a uniform balancing or readout (if the coincidence method is used).

The building up of the discrete quantity in the case of the balancing method can be carried out by means of tracking, scanning or order-by-order balancing.

In tracking balancing the value of the discrete quantity is made up in such a manner that the difference between the unknown and known quantities at any instant is tending to zero. This principle is used in certain types of autocompensators with decade resistance boxes and a balancing motor [10], as well as in automatic potentiometers with an electronic tracking circuit [6].

Digitizers with uniformly scanning balancing in which the discrete quantity is normally made up in the form of a periodically repeating step-shaped curve, is fairly widely used in measurements [16]. Digitizers with an unevenly scanned balancing are of interest. They provide the possibility of introducing nonlinear correction in a measurement result of perform nonlinear conversions of the measured quantity.

In digitizers with an order-by-order balancing the unknown quantity is compared with the known quantity as the latter is being built up according to its code. Thus a value of the discrete quantity equal to the unknown quantity is obtained [16].

If the known value is made up by a unit code, step-by-step balancing becomes uniform scanning balancing. It should also be noted that in digitizers based on the on the balancing method, the discrete quantity can be made up by means of repeated utilization (summation, multiplication, etc.) of a single-valued known quantity.

Let us now examine digitizers based on the method of coincidence between the unknown and the discrete quantities. Such digitizers can use either a tracking or periodic method of readout.

With a tracking readout it is possible at any instant to obtain the value of the discrete quantity which coincides with the unknown quantity. Counting the number of quanta in the remaining part of the scale which is not covered by a discrete quantity corresponding to the unknown quantity, or reading out the code corresponding to the value of a discrete quantity which coincides with the unknown quantity are the distinctive features of a tracking readout. A tracking readout with the discrete quantity expressed by means of a unit code is used, for instance, in linear displacement digitizers of an induction type or with a diffraction grating and a reversible counter [14,17], as well as in voltage amplitude analyzers [9]. A tracking readout of discrete quantities made up by other than unit codes is used, for instance, in linear or angle displacement digitizers with coding masks or matrixes by means of which the tracking device observes the variations in the measured quantity [17].

A periodic readout of the discrete quantity which coincides with the unknown quantity can only be made at definite time intervals either by counting the number of quanta in the portion of the discrete quantity uniform scale corresponding to the unknown quantity, or by reading the code which determines the value of the discrete quantity equal to the unknown quantity. A typical example of coincidence digitizers with a periodic readout and a discrete quantity built up in a unit code are time interval digitizers with reference pulse repetition frequency generators [11, 12,16 and others].

Thus, the methods of simultaneous comparison of the values of the unknown and discrete quantities can be classified in the following manner:

1) methods of balancing the unknown quantity by means of tracking, scanning and order-by-order balancing; and for discrete quantity values made up in a unit code, by means of tracking and uniform scan balancing:

2) methods of making the unknown and discrete quantities coincide by means of a tracking or periodic readout. When the discrete quantity value is made up in a unit code these methods can be called coincidence methods with tracking or periodic metering. If the discrete quantity values are made up in a code other than a unit code they should be known as coincidence methods with a tracking or periodic readout.

Let us make a few additional observations.

The measured quantity may be compared in the digitizer with another whose value is unknown and must be determined. In this instance the consecutive comparison method by means of substitution or calibration can be used.

Digitizers can utilize measuring methods in which the quantization step (the value of the quantum) can be changed according to the value of the unknown quantity. This method is used in digitizers with adaptable properties [6] or those with radioactive substances whose intensity of radiation is proportional to the value of the known quantity (radioactive thickness gauges), etc. It is assumed that in such digitizers the quantization step is determined in the course of measurements also by means of balancing or coincidence methods.

Classification of digitizers by their measuring means. With respect to their equipment digitizers can be divided into contact and contactless types. Contact and contactless methods can be used for comparing the unknown and known quantities, and digitizers can be constructed with contact and contactless components.

With respect to their control methods digitizers may be divided into automatic and manually set types. Let us note that some of the automatic digital instruments were developed from instruments with manual setting [6,12,18 and others].

Classification of output devices. According to the method of displaying the measurement results (readout) the output devices of digital instruments may be divided into visual display and recording types.

In addition to visual display and recording the results may be transmitted in the form of coded signals. The latter is important for remote indication of digital instrument readings and for feeding them to computers.

A digital instrument output device may use intermediate memories as well as units for producing signals which could control any required process.

SUMMARY

A classification schematic of digital instruments (Fig. 2) based on the above article includes the classification of digitizers by their method of comparing the unknown and known quantities, by the method used in measuring by their equipment and their output devices, that is, their method of presenting the results.

The examination of the design principles of digital instruments only with respect to these classifications shows a considerable variety of measuring methods for which these instruments can be used. It should be noted, however, that the above classification does not include many derived types of digital circuits. However, digital instruments based on intermediate types may be of great importance. Thus, for instance, the simultaneous utilization of digitizers and analogue instruments, which is characteristic for differential methods of measuring the difference between a discrete and an unknown analogue quantity, is employed in a considerable number of instruments [5,7]. In the category of intermediate types of digital instruments should also be included partly automatic instruments which comprise contact and contactless elements, digitizers based on the simultaneous utilization of different methods of comparing the unknown and known quantities, etc.

The proposed classification of digital instruments is undoubtedly not the only possible one. However, in our opinion, it covers the basic principles for designing digital instruments and indicates certain possible tendencies in their development.

In conclusion the author considers it his duty to express his gratitude to Corresponding Member of the Academy of Sciences, USSR K. B. Karandeev and to Prof. M. I. Levin for their valuable advice, as well as to candidate of technical sciences B. S. Sinitsyn and engineers B. V. Karpyuka and A. N. Kasperovich for the useful observations made by them in discussing the material dealt with in this article.

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DETERMINING RMS VALUES OF VOLTAGES FOLLOWING A RANDOM LAW OF VARIATIONS

Ya. I. Flid and A. S. Lifshits

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pp. 35-38, May, 1961

The majority of automatic control systems operate in the presence of disturbances which vary according to a random law. Hence in designing and operating these systems it is necessary to determine both the value of these dis-

turbances and their effect on the system. In this connection the random components of the input signals and the system's errors are usually evaluated. These random signals are characterized by their quadratic mean value.

Often random signals are fed to the system and converted into dc voltages. In simulating automatic control systems it is also necessary to deal with random dc voltages. Hence, the direct measurement of rms values of dc voltages varying according to a random law is of practical interest.

This article deals with the design principle and description of an instrument developed for measuring rms values of fandom varying dc voltages.

The instrument is designed for measuring stationary random signals whose spectral density lies in the range of 0.1-100 cps and whose amplitude may vary in the range of 0.1-100 v. The instrument can also measure the dc component of a random varying voltage. A standard UPT-4 operational amplifier of an electronic model was used in the construction of this instrument.

It should be noted that in the majority of practical cases the measurement and reproduction of random processes is made in accurately. Hence an instrument for measuring random voltages is not required to meet stringent requirements with respect to accuracy.

Design principles of the instrument and selection of basic parameters. It is known that the rms value of the voltage can be obtained from the formula

$$\sigma=\sqrt{\frac{1}{t_u}\int_0^{t_u}x^2(t)dt}, \tag{1}$$

where x(t) is the measured random voltage; t_u is the observation or integration time; σ is the rms value of the voltage.

The instrument should consist of a computer which measures the rms value expressed according to (1).

The measured voltage x(t) is fed to the input amplifier and after amplification is squared in a functional unit. Voltage $K_1^2K_2x^2(t)$ obtained at this unit's ouput is integrated in an integrator and fed to the measuring circuit in the form of a voltage

$$U_u=\int_0^{t_u}\frac{K_1^2K_2x^2(t)}{T}dt, \tag{2}$$

where U_u is the voltage at the integrator output; K_1 is the gain of the input amplifier; K_2 is the gain of the functional unit; T is the time constant of integration; t_u is the integration time.

In order to determine the rms value of voltage U_u it is necessary to divide the above expression by t_u, i.e.

$$\sigma^2=\frac{1}{t_u}\int_0^{t_u}\frac{K_1^2K_2x^2(t)}{T}dt. \tag{3}$$

If the instrument is made to provide a constant integration time, it can be accounted for as a constant coefficient. A constant integration time can be obtained by means of a stable pulse generator (multivibrator) with a relay at its output. The relay contacts are made to switch at given time intervals the integrating-unit output to the measuring circuit and discharge at the end of integration the integrating capacity.

The measuring circuit consists of a multivibrator, a switching relay and a tube voltmeter. If the measuring circuit is connected directly to the integrator output, the voltmeter readings will follow the voltage variations at the output of the integrator, which is inconvenient for a readout at the end of the integration interval. It is therefore advisable to connect between the integrator and the voltmeter a capacitor which stores the voltage obtained at the end of integration and measured on the tube voltmeter. In order to prevent the capacitor discharging through the integrating amplifier it is advisable to connect it only for a short interval Δt at the end of integration. The integration time

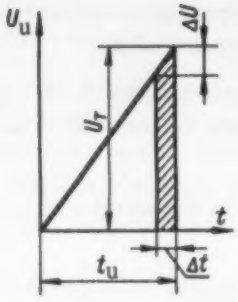

Fig. 1.

time is chosen so as to make the voltage at the end of integration an order higher than the alternating component at the integrator output; hence, in calculating the time interval Δt it is not necessary to consider the alternating component at the integrator output (Fig. 1)

Time interval Δt is chose in such a manner as to make the voltage variations at integator output in time Δt smaller than a given value.

It can easily be shown that if the output voltage variation is set at $\Delta = \Delta U/U_m = 0.01 - 0.02$, where U_m is the maximum voltage at the integrator output, then it is necessary to have

$$\Delta t = (0.01 \div 0.02)\ t_u. \tag{4}$$

Since U_u is proportional to σ^2, it is advisable to make the instrument scale nonlinear calibrated for direct reading of the rms value of σ.

It can be considered approximately that a random effect can be represented by a sum of harmonic effects with random amplitudes independent from each other. The amplitude of the variable component at the integrator unit output is inversely proportional to the signal frequency. We can deduce therefore that the ratio of the quadratic mean deviation of the output signal from its mean value (expectation value) will be maximum when a signal with a minimum frequency (ω_{min}) is applied to the input of the instrument. This ratio characterizes the accuracy of the instrument's operation. The minimum frquency of a random signal spectrum can usually be evaluated.

With the above considerations in mind it is possible to make an approximate computation of the integrator parameters providing the input of the instrument is fed with a sinusoidal voltage U_m of a minimum frequency $x(t) = U_m \cdot \sin\omega_{min} t$. The voltage at the output of the integrating amplifier will then be:

$$U_u = \frac{K_1^2 K_2}{T} \int U_m^2 \sin^2 \omega_{min} t\, dt = U_m^2 \frac{K_1^2 K_2}{T} \left[\frac{1}{2} t - \frac{1}{4\omega_{min}} \sin 2\omega_{min} t \right] \tag{5}$$

It will be seen from (5) that the voltage at the integrator output contains a variable component of a double frequency

$$U_{u\sim} = U_m \sin 2\omega_{min} t \left(\text{where} U_m = U_m^2 \frac{K_1^2\ K_2}{T 4\omega_{min}} \right) \tag{6}$$

and a constant component (more accurately, varying proportionately to the integration time)

$$U_{u=} = \frac{U_m^2\ \ K_1^2\ K_2}{2\ T}\ t. \tag{7}$$

Since the voltage is fed to the measuring circuit at the end of the integration interval, (7) will assume the form

$$U_{u=} = \frac{U_m^2\ \ K_1^2 K_2}{2\ T}\ t_u. \tag{8}$$

The accuracy of the instrument operation is determined to a great extent by the variable component of the measuring circuit output voltage. The relative value of this component δ can be determined by the ratio of the variable component amplitude to the constant component with a sinusoidal input, i.e.

$$\delta = \frac{U_m}{U_{u=}}\ . \tag{9}$$

By inserting in (9) the amplitude value of U_m from (6) and the value of $U_{u=}$ from (8) we obtain

$$\delta = \frac{1}{2\omega_{min} t_u} \cdot 100\%. \tag{10}$$

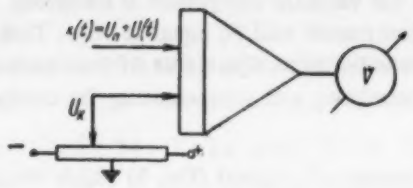

Fig. 2.

It will be seen from (10) that the value of relative pulsations is inversely proportional to double the frequency of the input signal and the integration time t_u. By setting the permissible pulsation value δ and a minimum frequency ω_{min} which is to be measured, it is possible to determine the required integration time

$$t_u = \frac{1}{2\omega_{min}\delta} \cdot 100. \qquad (11)$$

The frequency range (ω_{min}-ω_{max}) is determined by the spectrum of the random voltage which is to be measured.

From (8) we can determine the integrator time constant

$$T = \frac{U_m^2 \; K_1^2 \; K_2 \; t_u}{2 \; U_{u=}} \; . \qquad (12)$$

The value of $U_{u=}$ is taken to be equal to the maximum output voltage of the operational amplifier on the linear portion of its characteristic (in the UPT-4 amplifier used in this circuit $U_{out\ max} = 100$ v). The value of U_m is determined by the required measurement range of the random voltage amplitudes. The amplifications factors K_1 and K_2 are chosen to avoid overloading in the circuit components. By means of the above considerations it is possible to determine time constant T from (12).

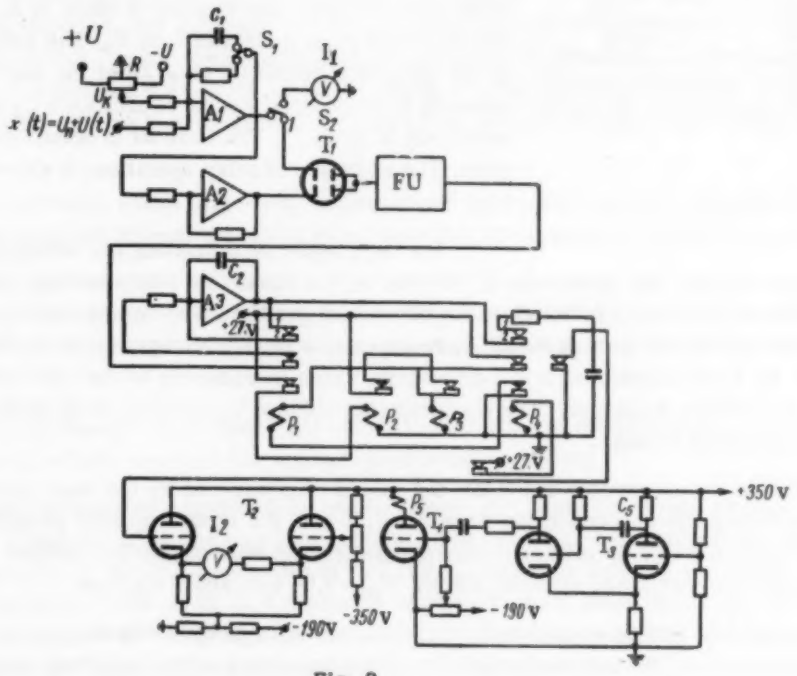

Fig. 3.

It should also be noted that the time constant of the memory cell T_m should be made small enough to allow the capacitor to charge in time Δt.

The measured random changing voltages may contain a constant component U_n, which should be determined and compensated before measuring the quadratic mean value of the variable component. This can be done if the measured voltage x(t) (avoiding the squaring device) is fed straight to the input of the integrator (Fig. 2). The output voltage of the integrator will rise with time only due to the constant component, since the variable component is alternating and will not produce a constant component at the integrator output. If the integrator input is fed by a

direct voltage U_K, equal to the constant component of the measured voltage, then the constant component of the integrator output voltage will not change for $U_k = \overline{U}_n$. When the rms value of the variable component is measured again after compensation, the integrator output voltage due to the constant component will be equal to zero. Thus, it is possible to compensate component U_n in the course of measuring the rms value of σ. The value of the constant component U_n can then be determined by measuring U_K. This method of determining and compensating the constant component has been adopted in the above instrument.

On the basis of the above guiding propositions it is possible to design instrument's circuit (Fig. 3) which would measure the rms value and the constant component of a voltage varying according to a random law.

The input device of the instrument consists of a dc operational amplifier denoted on the circuit by A1. The functional unit Fu, which squares the measured voltage, employs the principle of piecewise linear approximation and consists of two diodes brought into operation consecutively as the input voltage rises. Since the above unit can square voltage os one sign only, its input is connected to a signs circuit consisting of operational amplifiers A1 and A2 and a diode T_1.

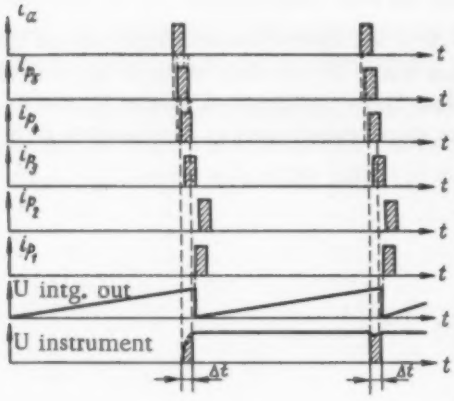

Fig. 4.

The integrating device consists of an operational amplifier A3 whose feedback contains capacitance C_2. The output voltage of the integrating amplifier is fed to the measuring circuit which provides a constant integrating time and measures the integrator output voltage. The integrating time t_u is determined by the working period of the pulse generator. The measuring circuit consists of a tube voltmeter (t_2 and pointer instrument I2), pulse generator (T_3 and T_4), a group of relays which switch the output of the integrating amplifier to the tube voltmeter, and discharge capacitance C_2 at the end of integration. Relays P_1, P_2, P_3 and P_4 work from a 27 v supply. The winding of relay P_5 is connected to the anode circuit of the pulse generator tube T_4. The tube voltmeter is connected to the integrator output for time Δt at the end of integration by means of contacts (1-2) of relay P_4 and capacitance C_1 is discharged through contacts (1-2) of relay P_1. The time Δt is determined by the relay operation time. The sequence of relay operations is shown in the time diagram of Fig. 4.

For the purpose of separating and determining the constant component of the measured voltage, the instrument is provided with a circuit for compensating this component. The input amplifier A1 is then connected by switch S_1 to an integrating position. The constant component voltage is integrated by amplifier A1 and connected through switch S_2 to instrument I1. The compensation is attained by feeding to the input of amplifier A1 from potentiometer R a dc voltage which increases up to the instant the voltage stops rising at the output of the integrating amplifier. The compensating voltage U_k is equal in its absolute value to the constant component of the measured voltage.

In the instrument we constructed the following values were adopted for the basic parameters: Integration time $t_u = 16$ sec; the measuring circuit connecting time $\Delta t = 0.16$ sec; the input amplifier amplification factors $K_1 = 0.77$, 7.7 and 77 respectively for various voltage measuring ranges; the squaring device transfer constant $K_2 = 0.01$; the time constant of the memory capacitance charging circuit $T_m = 0.04$ sec; and $T = 4.8$ sec.

Since the instrument uses dc operational amplifiers with a large open circuit gain ($\approx 5 \cdot 10^4$) and the circuit consists of precision components, the errors of amplifiers and integrators can be neglected. The errors of the instrument are determined in the main by the variable component at the integrator output ($\approx 5\%$) and the error of the squaring device ($\approx$ 1-2%), thus the quadratic mean error of the instrument amounts to $\approx 8\%$.

The instrument is supplied from a standard stabilized rectifier type ÉSV-1M.

In operation the instrument proved to be highly efficient.

HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

STANDARDIZING RADIO-MEASURING EQUIPMENT

L. M. Zaks and V. P. Rynkevich

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To date in the USSR there have been no standards for radio-measuring equipment, which had a negative effect on the organization of the production and the quality of instruments. The Committee of Standards, Measures and Measuring Instruments has now approved a basic standard which comes into force on July 1, 1961. The standard reads: "Instruments, radio-measuring. General technical requirements." It has also approved standards for tube voltmeters cathode ray oscillographs, and heterodyne and resonance frequency meters.

The standard "Instruments, radio-measuring. General technical requirements" is the first document both in the USSR and abroad which embraces the basic requirements for a wide range of different radio-measuring instruments of various types and used for different purposes under varied conditions. The standard specifies important metrological requirements and conditions for climatic and mechanical tests of radio-measuring equipment.

The following methods of expressing the basic errors are provided: in percentages of the measured value, of the full-scale deflections, and of the sum of full-scale deflections (for center-zero instruments), of the difference between the full-scale and initial readings (for suppressed-zero instruments), and of the length of the working part of the scale; in decibels with respect to the measured value; in relative values; in the form of an algebraic sums of two terms, one of which is proportional to the measured value and the other constant (for instance, the error in the output voltage of a standard signal generator $\delta = \pm (0.05\,x + 1)$ μv, where x is the measured value in μv). The value of additional errors due to extraneous effects is expressed in fractions of the main error, or in percentages of the measured value.

Side by side with instruments whose main error is guaranteed for normal climatic conditions, the manufacture of instruments whose error must not exceed the given value over the whole range of working temperatures and humidities is also provided.

The standard provides that the permissible error in checking must be at least 1/3 of the instrument error. The waiving of this stipulation is only allowed in special cases by permission of the Committee of Standards, Measures and Measuring Instruments.

With respect to the instruments' mechanical and climatic stability and reliability requirements, the standard divides them into five groups which cover all the typical operational conditions.

Group I covers the instruments intended for use in closed, dry, heated premises without being subjected to knocks or shocks when displaced from one bench to another. The operating climatic conditions for these instruments consists of a temperature of 10-35°C, humidity of 80% at 20°C; and their limiting conditions consist of a temperature of -40 to + 60°C, humidity of 95% at 20°C. Instruments of this group are subjected to mechanical toughness tests in transportation. The standards set for these tests are the same for all groups, consisting of shaking for 2 hr on a rack which vibrates at the rate of 2-3 oscillations per second with an acceleration of 3 g.

Group II includes instruments used in closed and heated premises and subjected to shocks and knocks when being displaced from one bench to another. Contrary to Group I instruments these instruments are tested for vibration resistance at one frequency for 10 minutes.

Group III instruments are inteded for working in closed, unheated premises and where they are likely to be subjected to frequent shocks and vibrations when being displaced from one bench to another in a nonoperating condition. The working climatic conditions for these instruments consist of a temperature between -10 and + 40°C, humidity of 90% at 25°C; and their limiting conditions consist of a temperature of -40 to + 60°C, humidity of 95% at 25°C. In addition to transportation shaking and vibration resistance tests at one frequency the above instruments are also tested for shock resistance for 10-15 minutes with the impact pulse lasting 10-12.5 msec, and a peak acceleration of 5 g.

The instruments of groups IV and V are intended for working in the open air under difficult metrological conditions and subjected to frequent shocks and shaking. Hence, they are provided with more stringent testing.

The standard also specifies other requirements common to all the instruments. For instance, instruments intended for operation from the mains at the commercial frequency of 50 cps must be designed for a nominal voltage of 220 v, a working voltage of 220 v ± 10%, and a frequency of 50 ± 0.5 cps. On special request of customers, instruments can also be made for supplies of 110/127/220 v and a frequency of 20 ± 2 cps. Radio-measuring instruments can be made for operation both into a matched and unmatched load. In the first instance the following range of output and input imedances is established: 5,50,75,150,300,500 and 600 ohm.

Operational safety precautions for these instruments provide that all external components at a voltage exceeding 36 v with respect to the chassis must be protected from accidental contact; in instruments with a voltage exceeding 1500 v and a short-circuit current exceeding 25 ma, interlocking is specified. Moreover, instruments supplied from the mains or high-voltage networks (exceeding 1500 v) must have separate terminals for grounding their chassis.

Separate standards for tube voltmeters, cathode-ray oscilloscopes, heterodyne and resonance frequency meters establish requirements and methods of testing for these instruments.

Each standard specifies the grade of accuracy corresponding to the instrument. Thus, for tube voltmeters seven grades of accuracy are established with respect to the referred basic error, namely, of 0.5, 1.0, 1.5, 2.5, 4.0, 6.0 and 10.0%.

Cathode-ray oscilloscopes are divided into four grades, characterised by the relative errors in measuring amplitudes and time parameters of signals. For the first three grades these values are 3,5, and 10% respectively. For grade 4, error tolerances are not guaranteed by the standard but should be set by the specification for the given oscilloscope. Oscilloscopes are also graded with respect to accuracy of the signal shape reproduction. For instance, grade 1 oscilloscopes must have a minimum distortion of the signal shape and a minimum diameter of the spot.

For heterodyne frequency meters three grades of accuracy have been established, which correspond to the following relative error in measuring frequency: 0.0005, 0.005 and 0.05%. Resonance frequency meters are divided into five grades of accuracy corresponding to errors of 0.01, 0.05, 0.1, 0.5 and 1%.

The classification of instruments into grades of accuracy corresponds to the present stage of development of measurement techniques and provides an increase in the types of instruments with a higher accuracy.

The introduction of standards for radio-measuring equipment is of great importance to the whole of the radio and electronic industry of the USSR. The higher standards and methods of testing as compared with the existing ones, which have now been adopted, will raise the operational properties of our radio measuring equipment. The unification of the general requirements and the establishment of standard testing methods will facilitate the combined use and comparison of different type instruments. The specification of grades of accuracy in groups of instruments will, to a considerable extent, eliminate the multiplicity of instruments used for the same purpose.

All the radio-measuring-instrument plants should be fully prepared to change over for the production of instruments according to the new standards. In the first place this preparation should consist of equipping the plants with reference measuring instruments and other checking and testing equipment required for testing instruments according to the methods established in the standard. This includes, among other things, racks for mechanical testing, humidity chambers, thermostats, etc. In the second place it is necessary to revise the technical specifications for all the radio-measuring instruments in production in order to make them correspond to the new standards, especially with respect to their methods of testing.

The GKIs (State Inspection Laboratories) should play an important part in introducing these standards. They should check whether the plants are ready to start production according to the new standards. It is necessary to check the availability in the plants of testing equipment specified by the standards, and when the standards are introduced to check their implementation.

THEORY OF A REACTIVE METHOD FOR MEASURING DIELECTRIC LOSSES

M. S. Mikitinskii

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Type IPP direct-reading meters of dielectric losses in capacitors are now being widely used. These meters are based on the so-called reactive method of measuring losses, which requires a close coupling between the measuring circuit and the tuned circuit of a high-frequency oscillator.

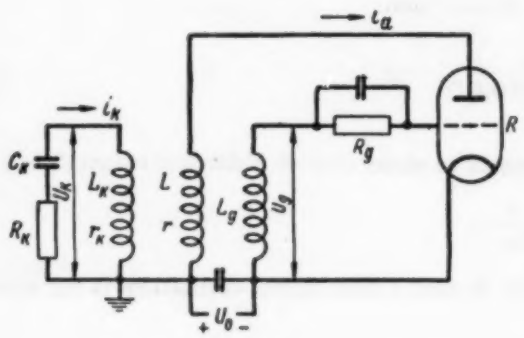

Fig. 1.

The theory of the reactive method is dealt with in paper [1] which in addition to general principles also examines the peculiarities of instruments operating on the basis of this method. Special attention is paid to instruments types ISK and IMK for testing the scintillation effect in capacitors. As far as type IPP instruments are concerned it is of interest to derive in an explicit form the relation between its readings and the measured loss angle.

In further expositions the principle of operation of the IPP instruments is assumed to be known.

Current amplitude in the measuring circuit. A simplified schematic of the IPP high-frequency circuit is shown in Fig. 1. Here C_k is the measured capacitance, R_k is the resistance equivalent to its losses.

The expression for damped oscillations in a tuned circuit has the form:

$$i_k = e^{\alpha t}\,(C_1 \cos \omega_1 t + C_2 \sin \omega_1 t), \tag{1}$$

where

$$\alpha = -\frac{R_k + r_k}{2L_k};\quad \omega_1 = \sqrt{\frac{1}{L_k C_k} - \left(\frac{R_k + r_k}{2L_k}\right)^2}. \tag{2}$$

Constants C_1 and C_2 are found from the initial conditions. For $t = 0$ there is no current in the circuit, hence $C_1 = 0$. In order to determine constant C_2 it is necessary to determine the voltage across the circuit at $t = 0$. This voltage is

$$U_k = -M_{ak}\frac{di_a}{d\tau}, \tag{3}$$

where M_{ak} is the mutual inductance between the anode and tuned coils, i_a is the shorting extra-current in the anode circuit, τ is the time interval preceding oscillations in the circuit.

The equation for the anode circuit extra-current

$$(R + r)\,i_a = U_0 - L\frac{di_a}{d\tau} \tag{4}$$

has as its solution an implicit function

$$U_0 - (R + r)\,i_a = C\exp\left(-\frac{R + r}{L}\,\tau\right), \tag{5}$$

where U_0 is the anode supply voltage, and constant C is found from the condition that for $\tau = 0$ current $i_a = i_{a0}$ or, for simplicity $i_{a0} = 0$ (the instrument is disconnected); moreover $C = U_0$.

At the same time the voltage across the tuned circuit is:

$$U_k = -L_k \frac{di_k}{dt}. \tag{6}$$

In comparing (3) and (6) we note that instant $t = 0$ (beginning of oscillations in the circuit) corresponds to $\tau = \tau_0$ (end of the transient period in the anode current). Then:

$$C_1 = \frac{M_{ak}}{LL_k} \frac{U_0}{\omega_1} \exp\left(-\frac{R+r}{L} \tau_0\right).$$

Considering the smallness of τ_0 (the oscillations reach a stable state quickly) we have

$$C_2 = \frac{M_{ak}}{LL_k} \frac{U_0}{\omega_1}. \tag{7}$$

Expression (1) for damped oscillations now assumes a fully defined form:

$$i_k = \frac{M_{ak}}{LL_k} \frac{U_0}{\omega_1} e^{\alpha t} \sin \omega_1 t. \tag{8}$$

Let the first amplitude of damped oscillations which corresponds to phase

$$\omega_1 t = \frac{\pi}{2}, \quad \text{or} \quad t = \frac{\pi}{2\omega_1},$$

be sustained by an oscillator as a stable-state oscillation amplitude. In such a case current oscillations in the measuring circuit are represented by the function:

$$i_k = \frac{M_{ak}}{LL_k} \frac{U_0}{\omega_1} \exp\left(\frac{\pi}{2} \frac{\alpha}{\omega_1}\right) \sin \omega_1 t. \tag{9}$$

The amplitude of these oscillations can obviously be expressed in terms of the loss angle tangent of the capacitor under test. Considering that $1/\sqrt{L_k C_k} = \omega$ is the natural frequency of the tuned circuit, we obtain from (2):

$$\frac{\alpha}{\omega_1} = -\frac{\omega (R_k + r_k) C_k}{2\sqrt{1 - \left[\frac{\omega (R_k + r_k) C_k}{2}\right]^2}}.$$

Since instruments of the IPP type are intended for measuring tg $\delta = \omega RC$ of the order of $(10^{-4}\text{-}10^{-3})$, it is possible to neglect second order quantities with respect to (ωRC), then we have

$$\frac{\alpha}{\omega_1} = -\frac{\omega (R_k + r_k) C_k}{2}. \tag{10}$$

By expanding the exponent of (9) into a series and taking only the first order terms with respect to (ωRC) we obtain the current amplitude in the measuring circuit:

$$i_{km} = \frac{M_{ak}}{LL_k} \frac{U_0}{\omega_1} \left[1 - \frac{\pi}{4} \omega (R_k + r_k) C_k\right]. \tag{11}$$

Anode current dc component. From (9) and (11) it is easy to determine the voltage across the grid circuit coil

$$U_g = -M_{kg} \frac{di_k}{dt} = U_{gm} \cos \omega_1 t,$$

where

$$U_{gm} = \frac{M_{ak} M_{kg}}{LL_k} U_0 \left[1 - \frac{\pi}{4} \omega (R_k + r_k) C_k\right]. \tag{12}$$

Let us use the well-known relations:

$$M_{ak} = \chi_1 \sqrt{L L_k},$$
$$M_{kg} = \chi_2 \sqrt{L_k L_g},$$

where χ_1 and χ_2 are the respective coupling coefficients. Then (12) will assume the form:

$$U_{rm} = \chi_1 \chi_2 \sqrt{\frac{L_g}{L}}\, U_0 \left[1 - \frac{\pi}{4}\omega (R_k + r_k) C_k\right]. \tag{13}$$

The grid characteristic of the oscillating triode in the IPP sets is sufficiently accurately represented in [2] by the function:

$$i_g = a e^{bU_g},$$

where coefficients a and b can be found experimentally. For tube 6S2S (Fig. 2) a = 15μa, b ≈ 5 v^{-1} and U_{a0} = 60 v.

The grid current dc component is determined on the basis of the theory of trigonometrical series:

$$i_{g0} = \frac{1}{2\pi}\int_0^{2\pi} i_g\, d(\omega_1 t) = \frac{a}{2\pi}\int_0^{2\pi} e^{bU_{gm}\cos\omega_1 t}\, d(\omega_1 t),$$

which makes it possible to write:

$$i_{g0} = a\Lambda_0 (bU_{gm}). \tag{14}$$

where

$$\Lambda_0 (x) = \frac{1}{2\pi}\int_0^{2\pi} e^{x\cos\varphi}\, d\varphi -$$

is a cylindrical function of the 1st kind, zero order of a purely imaginary agrument. The value of U_{gm} is determined by expression (13). The anode current dc component which is of interest to us will be represented as:

$$I_{a0} = SE_{g0} + SR_g i_{g0}, \tag{15}$$

where E_{g0} is the negative dc grid bias, S is the slope of the anode-grid characteristic.

Reading of an indicating instrument. The last stage of an IPP set consists of a dc bridge, one of whose arms includes an oscillating tube (Fig. 3). The current through the bridge measuring diagonal is

$$i_0 = i_1\left(1 + \frac{R_1 + r}{R_2}\right) - \frac{E_0}{R_2}, \tag{16}$$

where R_1 is the internal resitance of the tube; r is the ohmic resistance of the anode coil, and current i_1 is equal to the dc component of the tube anode current I_{a0}.

Considering that

$$I_{a0}(R_1 + r) = U_0,$$

we shall obtain for the readings of an indicating instrument:

$$i_0 = I_{a0} + \frac{1}{R_2}(U_0 - E_0). \tag{17}$$

Relationships (13), (14), (15) and (17) provide an explicit expression of the relation between the indicating instrument readings and the loss angle (tan δ = $\omega R_k C_k$) of the capacitor included in the oscillatory circuit:

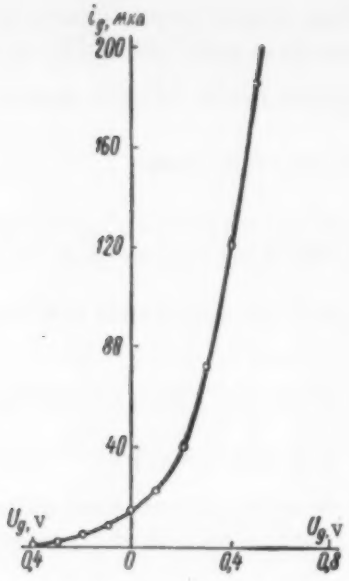

Fig. 2. Grid characteristic of triode 6S2S.

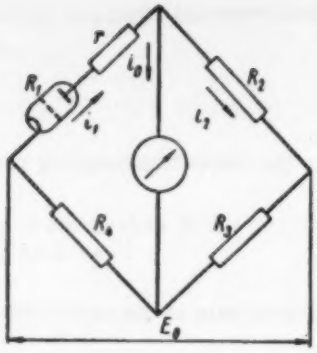

Fig. 3.

$$i_0 = \frac{1}{R_3}(U_0 - E_0) + SE_{g0} + SR_g a\Lambda_0 \left\{ b\chi_1\chi_2 \sqrt{\frac{L_g}{L}}\, U_0 \left[1 - \frac{\pi}{4}(\tan\delta + \omega r_k C_k) \right] \right\} \quad (18)$$

SUMMARY

Expression (18), in which function Λ_0 is obtainable in a tabulated form [3], relates the quantities which are to be measured with the parameters of the measuring circuit. Expression (13) can also be used for selecting the grid voltage amplitude for a sufficiently close coupling and the optimum anode supply voltage.

Moreover, an analysis of (18) provides a linear scale for the instrument over a sufficiently wide range. This is confirmed experimentally by means of loss angle standards for frequencies of 0.3 and 1.0 Mc developed by the VNIIM (All-Union Scientific Research Institute of Metrology). The residual loss of the instrument determined by means of two loss angle standards of the same capacitance (the error due to the ohmic resistance of the tuned circuit coil is excluded) remains the same over the whole scale.

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EQUIPMENT FOR MEASURING THE IMPEDANECE OF DUCT CAPACITORS

A. Kh. Karasik

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pp. 43, May, 1961

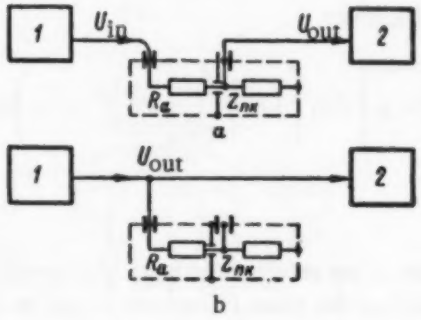
Duct capacitors are widely used in various noise-suppressing devices. The filtering properties of a duct capacitor are characterized by its impedance (Z_{nk}) over a wide frequency range.

A special equipment was developed for measuring this impedance over a range of 0.04-0.25 ohm at frequencies of 0.16-400 Mc. The error in measuring the impedance up to 20 Mc does not exceed ±20%, up to 150 Mc ±30%.

The impedance is measured according to the technique described in GOST (All-Union State Standard) 6760-53 (p. 41). This measurement consists in comparing the impedance of the capacitor with a reference ohmic resistance R_0. If R_0 is large (in our set it is equal to 400 ohm) the value of the impedance is determined from the formula

$$Z_{nk} = \frac{U_{out}}{U_{in}} R_0.$$

The meaning of quantities U_{out} and U_{in} is made clear on the attached circuit (see Fig.).



a) setting voltage U_{in} and recording voltage U_{out}; b) measuring voltage U_{out}; 1) high-frequency oscillator; 2) noise-meter.

The reference resistor and measured capacitor are placed in a special screened chamber which eliminated any effects of extraneous radio signals on the measurement and neutralizes the coupling between the input and the output circuits of the set.

The measuring circuit is fed from a high-frequency oscillator with voltage U_{in} whose value is read off the oscillator voltmeter, and the value of the output voltage U_{out} is measured on the noise-meter. The oscillator is then connected directly to the noise-meter and adjusted to the above voltage whose value is determined by the voltmeter and the oscillator attenuator readings.

The high-frequency voltage level is measured by noise-meters IP-12M or IP-14.

In order to facilitate the calculation of Z_{nk} with its frequency corrections special nomograms are supplied.

In order to check the measurement error, duct capacitors of various nominal values from 300 μμf to 0.5 μf were tested, in a frequency range where their impedance is capacitative and can be calculated.

The above tests confirmed the measurement errors previously cited.

PRECISION RADIO-FREQUENCY PHASE-METER

M. M. Karliner

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Phase-meters based on the conversion of the measured phase difference into the duty factor of rectangular voltages [1,2] have acquired a wide application in recent years. The advantage of such phase-meters consists in their range of 0 to 360° and their linear scale.

Their main disadvantages consist in their complexity and inaccuracy in measuring small angles of the order of 10-20°

Let us illustrate the operation of the phase meter by means of schematics (Fig. 1).

Alternating voltage U_1 is added and subtracted from voltage U_2. The resulting voltages are rectified by means of detectors D1 and D2. The phase-meter output voltage consists of the difference of the detector output voltages.

Let us examine the phase-meter operation at various ratios of the amplitudes of input voltages $\dot{U}_1$ and $\dot{U}_2$. The phase-meter output voltage is

$$U_{out}=|\dot{U}_1+\dot{U}_2|-|\dot{U}_1-\dot{U}_2|=\sqrt{U_1^2+U_2^2+2U_1\cdot U_2\cos\varphi}-\sqrt{U_1^2+U_2^2-2U_1\cdot U_2\cos\varphi}, \quad (1)$$

where U_1 and U_2 without dots are the amplitudes of the corresponding input voltages. It will be seen from (1) that the output voltage depends on the amplitude of both input voltages and of the phase difference between them. It can easily be shown that if the amplitude of one of the voltages is considerably larger than that of the other, the output voltage of the phase-meter will be almost independent of the larger amplitude of one of the voltage of the phase-meter will be almost independent of the larger amplitude. For instance, let $U_1 \gg U_2$, then:

$$U_{out}=U_1\left[\sqrt{1+\left(\frac{U_2}{U_1}\right)^2+2\frac{U_2}{U_1}\cos\varphi}-\sqrt{1+\left(\frac{U_2}{U_1}\right)^2-2\frac{U_2}{U_1}\cos\varphi}\right]\approx U_1\left[1+\frac{1}{2}\left(\frac{U_2^2}{U_1^2}+2\frac{U_2}{U_1}\cos\varphi\right)-\right.$$
$$\left.-1-\frac{1}{2}\left(\frac{U_2^2}{U_1^2}-2\frac{U_2}{U_1}\cos\varphi\right)\right]=2U_2\cos\varphi. \quad (2)$$

Thus, if the input signal is several times larger than the amplitude of the reference voltage, the output voltage of the phase-meter will depend only on the reference voltage amplitude and the phase difference. It can be shown that if the signal amplitude U_1 is made sufficiently large, the relative error of the phase-meter output voltage will not exceed:

$$\frac{\Delta U_{out}}{U_{out}}=-\frac{1}{2}r^2\sin^2\varphi, \quad (3)$$

where $r=U_2/U_1 \ll 1$. This error is at a maximum for $\sin\varphi=1$, hence for

$$\frac{\Delta U_{out}}{U_{out}}=-\frac{1}{2}r^2. \quad (4)$$

In order to keep the error within 1% it is sufficient to have $r \leq 1/7$, i.e. the input signal must be 3.5 times greater than the reference voltage $2U_2$.

For the condition of $r \ll 1$ the phase-meter scale becomes cosinusoidal, i.e. the phase-meter output voltage is equal to zero for $\varphi=90°$. For convenience of measurements an additional phase-shift of 90° is introduced in order to make the output phase-meter voltage equal zero for a zero phase-shift. Then the indicating instrument readings will be equal to $N=k\cdot\sin\varphi$, where k is a coefficient. A sinusoidal scale makes the phase-meter calibration easy. In fact, it will be found if the phase difference is varied smoothly by means of a phase-shifter that the maximum reading is obtained when $\varphi=90°$. In this case $N_{max}=k$.

Thus, the value of k is determined as the maximum indicator reading for a varying input signal phase

$$N=N_{max}\cdot\sin\varphi. \quad (5)$$

If the instrument scale is uniform and contains 100 divisions, it is advisable to select the sensitivity in such a manner that the maximum instrument reading should correspond to 100 divisions. In this case a direct reading of $\sin\varphi$ from the instrument scale is obtained: $\sin\varphi=N/100$.

The phase-meter consists (see simplified schematic in Fig. 2) of two detectors T1 and T2. The input signal and reference voltages are supplied through two transformers Tr1 and Tr2. The phase-meter output voltage is fed to the input of a balanced cathode follower T4 and T5 whose output is connected to an indicating instrument I1. A potentiometer in the cathode of T5 provides the balancing of the cathode followers.

The purpose of detector T3 consists of the following: Although the output phase-meter voltage, which is equal to the voltage difference at the outputs of detectors T1 and T2, does not depend on the amplitude of the input volt-

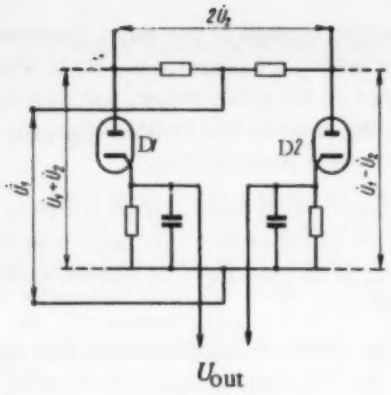

Fig. 1.

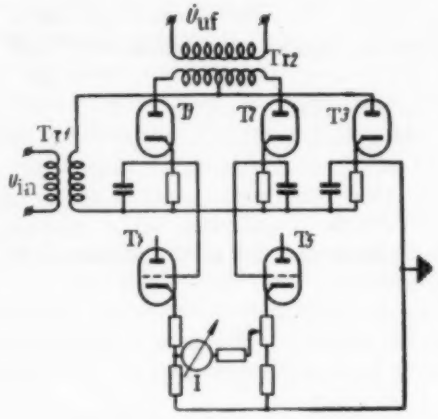

Fig. 2.

age, these voltages can nevertheless vary over a considerable range while U_{in} is being measured. When the voltages fed to the inputs of the balanced cathode followers are raised considerably, the cathode followers may become unbalanced owing to a difference in the T4 and T5 tube characteristics. In order to avoid this possibility detector T3 is incorporated whose output voltage is equal to the amplitude U_{in}. This voltage is connected in such a manner that it subtracts from the voltages at the output of detectors T1 and T2. As a result of this the mean grid potential of triodes T4 and T5 always remains equal to zero, and the potential difference between them to the phase-meter output voltage. This provides an operating condition for the cathode follower independent of the input signal amplitude.

The phase-meter model had three scales corresponding to the maximum phase-difference angles of 10, 30 and 90°. The instrument was calibrated on the 0-90° scale by means of a phase-shifter in the input signal circuit. A smooth adjustment of the phase-meter sensitivity was attained by varying the reference voltage amplitude U_{ref}, and a sudden adjustment in changing from one scale to another by varying the resistance in the indicating instrument circuit.

For a normal operation of the phase-meter circuit it is important to eliminate capacitative coupling between the primary and secondary windings of the reference voltage transformer Tr2, as well as any coupling between the input signal and reference voltage circuits. Only if these conditions are met do the phase-meter readings become practically independent of the input signal amplitude (when the latter is sufficiently large). Hence a careful screening of the appropriate circuits is required.

A full phase-meter circuit is given in Fig. 3. In this circuit T1 and T5 are the reference voltage and signal amplifiers respectively. The reference voltage is fed after amplification through the cathode follower T2 and transformer Tr2 to detector T3. The signal is fed to the midpoint of transformer Tr2. After detection the output phase-meter voltage is fed to the balanced cathode follower T4. The left half of T6 is a signal detector. Its right half is a cathode follower whose cathode is connected to the signal amplitude measuring instrument.

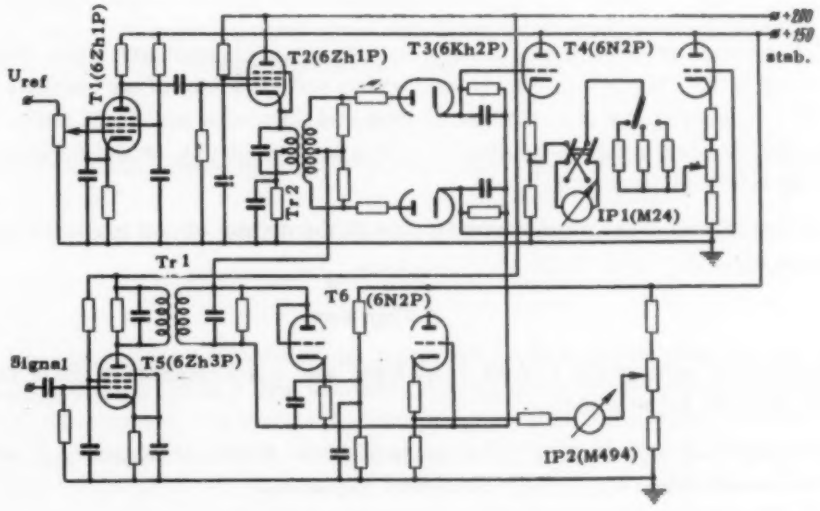

Fig. 3.

The above phase-meter operates in conjunction with a phase-shift unit which consists of two series connected phase-shifters. One of these provides a phase variation of 0-360° and is used for setting the phase-meter scale. For this purpose the input signal phase is varied until a maximum reading is obtained on the phase-meter, and then by means of an adjustment of the reference voltage amplitude the instrument reading is set to 100 divisions (i.e., for the full scale). The indicating instrument pointer is then returned to zero by means of the phase-shifter.

The second phase-shifter provides a phase shift of 0-30°. It consists of a low Q (4-5) tuned circuit, which is detuned by means of a variable capacitor. An analysis of this phase-shifter shows that it can be calibrated with an error not exceeding 2% if the calibration of the variable condenser is known with great precision. This phase-shifter can be used for measuring accurately the phase difference by a compensation method.

The phase-meter error was determined experimentally. For this purpose the above accurate phase-shifter was used. By means of it the 0-10° and 0-30° scales were checked. On either scale the error does not exceed 3% of the respective full-scale deflections.

The relation between phase-meter readings and the amplitude of the input signal was also determined. For this purpose the amplitude of the input signal was first set at a value 4 times greater than the reference voltage, and it was then changed by ±25%. When this was done the maximum variations in the readings of either scale (0-10° and 0-30°) did not exceed ±1%.

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TRANSISTORIZED REGENERATIVE FREQUENCY DIVIDER

E. I. Dolbak

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The phase characteristics of frequency dividers do not remain constant with time. They vary with mains voltage oscillations owing to the "aging" of circuit components and variations of the ambient temperature. This leads to variations in the frequency of the converted oscillations and, hence, to additional errors, whose value for certain types of frequency dividers (for instance, for dividers with a self-excited LC oscillator) may become comparable with the instability of the reference frequency.

Phase shift β (in radians) of the current passing through the divider circuit is related to the time of its transmission by the following equation

$$\beta = 2\pi f t + n\pi, \tag{1}$$

where f is the frequency of oscillations; t is the delay time, sec; n is the number of phase variations over 180° for a current transmitted over the entire circuit.

If during a certain time a phase change $\Delta\beta$ occurred in the divider at frequency f, this frequency will have after transformation an additional error, determined from expression:

$$\Delta f = \frac{\Delta\beta}{2\pi t_1}. \tag{2}$$

Whence the value of the relative error will be:

$$\frac{\Delta f}{f} = \frac{\Delta \beta}{2\pi t_1 f}. \qquad (3)$$

According to (1) a phase shift at a known frequency can be expressed directly in units of time. In quartz-crystal clocks where frequency f is divided down to f/n, the total phase change in separate circuit elements of the divider appears as a displacement in time of the second reference points, i.e. leads to variations in the clock readings. Hence, the frequency error due to the divider circuit phase instability can be expressed both in relative and time units.

Requirements of high phase stability are met satisfactorily by dividers with "driven" blocking-oscillator, phantastron and regenerative tube conversion circuits, which are now being increasingly used. The above dividers have very valuable properties when used in quartz-crystal clocks, namely, they do not provide an output voltage when the voltage of the divided frequency is absent at the input.

The above tube dividers, however, have certain disadvantages. Thus, the large number of tubes used by them leads to an increase in their size and a lack of reliability and economy in their operation. Phantastron dividers possess a high phase stability with variations of the mains voltage over wide ranges, but their scaling factor depends to a great extent on the circuit parameters and tube characteristics. A defect common to the above relaxation type dividers is the impossibility of obtaining sinusoidal voltages for frequencies which are multiples of the initial frequency. Moreover, in order to provide stable phase characteristics for tube dividers it is necessary to stabilize their anode and heater supply voltages. This leads to a rise in the number of tubes used and, hence to an increased power consumption and probability of failures.

Hence, the replacement of tubes by junction transistors in the above dividers is of considerable interest. Transistorized instruments have a long life, small dimensions and are economical in operation. Reference frequencies may be divided by means of binary scaling circuits using ferrite-transistor triggers with a feedback for obtaining a decimal code, by ring ferrite-transistor dividers, "driven" blocking-oscillator or regenerative frequency dividers.

Below we give the basic characteristics and test results of one of the possible versions of a regenerative frequency divider circuit for a range of 1 Mc to 1 kc, which uses transistors P14 and P15 and meets the above-mentioned requirements of frequency dividers for quartz crystal clocks.

Regenerative frequency divider. Decade frequency division is obtained by a consecutive switching-in of dividers with a scaling factor of 2 and 5. The attached figure shows a divider decade circuit operating from 100 to 10 kc. The divider circuits operating from 1 Mc to 100 kc and from 10 to 1 kc are similar to the above, with the exception of the circuit parameters.

The first stage of the regenerative divider with a scaling factor of 2 consists of a balanced modulator using point-contact diodes D_1-D_4 and a transistor T_3 tuned amplifier. A balanced modulator will have at its output only the sum and difference of the two input voltage frequencies, i.e.,

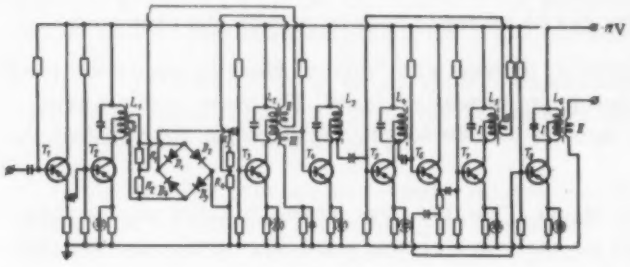
$$f_{out} = f_{in} + f_m, \qquad (4)$$

where f_m is the modulating frequency fed to the modulator from winding II of the L_2 circuit. Since the stage scaling factor is 2, we have

$$f_m = f_{out} = \frac{f_{in}}{2} \qquad (5)$$

At the instant the frequency divider is switched-in, frequency $f_{in}/2$ is absent. However, the input of the transistor T_3 amplifier has always a voltage across it of a frequency ranging from zero to infinity, produced by noise, transients due to switching and other causes. The tuned amplifier picks out of that spectrum frequency $f_{in}/2$, which is fed to the modulator. The sum and difference of frequencies f_{in} and $f_{in}/2$ are transmitted from the modulator output. Since circuit L_2 is tuned to the difference frequency, the regeneration conditions tuned to the difference frequency, the regeneration conditions will only be met by frequency $f_{in}/2$. After amplification frequency $f_{in}/2$ is again fed to the modulator. The voltage amplitude of frequency $f_{in}/2$ rapidly rises to a value determined by the modulator and amplifier parameters.

If a voltage of the divided frequency is not fed to the modulator input, oscillations will not arise, since the feedback circuit passing through the modulator will, in that instance, be disconnected. At high frequencies with incorrectly chosen modulator parameters a direct feedback may arise. In this case oscillations at a frequency close to $f_{in}/2$ may start in the divider. This frequency is easily synchronized by the input frequency f_{in}. Such an operating condition should be avoided, since the divider will produce at its output frequencies close to $f_{in}/2$ without the presence at its input of the reference frequency voltage.



The first scaling stage from 100 to 50 kc consists of a balanced modulator using diodes and a triode T_3 tuned amplifier. In order to keep the modulator balanced the forward and the reverse diode resistances must be made equal by appropriate selection. It is also necessary that $R_6 = R_7$ and $R_8 = R_9$.

The transistor T_1 emitter follower provides an input impedance of the order of several tens of kilohms. The preliminary amplification of the frequency of 100 kc is carried out by means of the transistor T_2 amplifier. In order to reduce the shunting of the tuned circuit by the transistors, their collectors are included in the transformer winding. The inductive coupling between tuned circuits L_1 and L_2 (with transformers of ratios 5:1 and 4:1 respectively) and the modulator are provided by matching the relatively high output impedances of the amplifiers to the low impedance of the modulator. An inductive coupling between the amplifiers and the modulator also facilitates the balancing of the latter.

The synchronizing band of the divider is equal to 70 kc and its value is determined mainly by the selectivity of tuned circuits L_1 and L_2. The divider operates with a supply voltage ranging from 2 to 25 v. Owing to the additional amplification by means of transistor T_2, the divider operates stably with input voltage varying from 15 mv to 5 v.

In a regenerative divider with a balanced modulator it is easy to provide division by a factor other than two. In such a case it is necessary to add to the circuit a frequency multiplier. It is possible to obtain higher scaling factors even without the use of frequency multipliers, since a modulator with germanium point-contact diodes has a characteristic of a higher order than two. Scaling factors up to 20 were obtained for a divider using a balanced modulator circuit with the parameters shown in the above figure. However, higher scaling factors require the use of high-Q tuned circuits in order to prevent the possibility of an output voltage appearing at other subharmonics of the input frequency. In this case the divider operation is disrupted by small variations in the supply voltage.

In order to produce regeneration in the divider it is necessary that its amplifier gain for a frequency of $f_{in}/2$ should be considerably higher than the loss in the modulator. For this purpose the current gain β of the common emitter transistor circuit must be at least 60.

The second divider stage using transistors T_5, T_6 and T_7 provides the division from 50 to 10 kc. Transistor T_5 is used as a mixer, and transistor T_7 as a frequency multiplier. The base of transistor T_5 is fed with 50 kc from the buffer transistor T_4 amplifier, and with a voltage of 40 kc from the secondary winding of tuned circuit L_5. The difference frequency of 10 kc is produced across tuned circuit L_4 and fed to the buffer stage consisting of transistor T_6 in an emitter follower circuit. From the emitter follower load the 10 kc voltage is taken to the frequency multiplier, then to the transistor T_8 tuned amplifier.

In a manner similar to the preceding stage, there will be no divided frequency (10 kc) voltage at the output of the divider in the absence of an input frequency voltage of 50 kc.

At the switching-in instant regeneration starts in a similar manner to the preceding stage, when 40 kc is picked out of the fluctuation voltage at the input of multiplier T_7. The amplified 40 kc voltage is fed to the mixer. The difference frequency of 10 kc is produced across the tuned circuit L_4 and fed to the emitter follower, which provides a large number of 10 kc harmonics. The multiplier picks out easily the fourth harmonic of 40 kc, amplifies it and feeds it again to the mixer. The oscillations grow rapidly in amplitude, which is determined by the set operating condition of the transistors.

It is possible to use similar dividers with a scaling factor exceeding 5. Tests of such a divider with a scaling factor of 10 (10 kc to 1 kc) showed that it was stable with input frequency voltage variations amounting to 60% and

supply voltage variations from 7 to 18 v. Its synchronizing band was about 300 cps. The divider consisted of three P14 transistors and cores SB-4a and SB-5a.

In order to compensate variations in triode characteristics with temperature and reduce the effect of the spread in transistor parameters, a negative dc feedback was used. The divider stage with a scaling factor of 2 was tested at temperatures of 20 to 75°C, and the output voltage amplitude did not vary by more than 20%.

The second stage of the divider operates at temperatures up to 65°C. Variations of its output 10 kc voltage and the current it consumes from the battery for temperature variations between 20 and 55°C did not exceed 3-4%.

Owing to the application of the negative feedback the divider transistors are interchangeable. However, in changing the transistors the current gain β of transistors T_3, T_5 and T_7 in the common emitter circuit should not be allowed to drop below 60, and for the remaining transistors below 30. It is also necessary for the transistors to have initial collector currents I_{ko} not less than 10 μa.

The last two decades of the divider use P14 transistors and the first decade P15 and P14 transistors. The total current consumption from a 12 v source for the three divider stages (from 1 Mc to 1 kc) amounts to 60 ma.

Divider tuned circuits data. The divider tuned circuits use shell-type carbonyl cores with three-section pile windings of PÉL-0.16 wire. The transformer designation, core type, winding and the number of turns are given below.

L_1, SB-3a, I, 120 + 80 turns; II, 40 turns.
L_2, SB-3a, I, 120 + 80 turns; II, 50 turns; III, 30 turns.
L_3, SB-3a, I, 150 + 50 turns; II, 50 turns.
L_4, SB-4a, 800 + 400 turns.
L_5, SB-3a, I, 100 + 50 turns; II, 40 turns.
L_6, SB-4a, I, 600 + 300 turns; II, 200 turns.

The remaining divider decades used carbonyl shell cores type SB-1a from 1 Mc to 400 kc; type SB-3a from 100 to 40 kc; type SB-4a from 10 to 4 kc; and type SB-5a for 1 kc.

Each divider decade is mounted on a perspex plate of 200 x 100 mm.

Main frequency-divider test results. Two decades which provide division from 100 to 1 kc were investigated.

1. The divider operates with the 100 kc voltage varying from 15 mv to 5 v. The total phase shift in the divider is then so small that it is impossible to measure it.

2. Its synchronizing band is equal to 8 kc and it remains constant with the 100 kc voltage varying in the above range.

3. The divider operation is not affected by supply voltage variations between 2.5 and 25 v.

A variation in the supply voltage from 15 to 5 v results in a phase shift of 18 μsec over the whole divider circuit, which amounts to $2 \cdot 10^{-10}$ when referred to a relative frequency variation. If the supply voltage tolerances are reduced to $\pm 5\%$ the phase shift will produce relative frequency variations not exceeding $1 \cdot 10^{-11}$, i.e. one or two orders lower than the frequency instability of the best modern quartz-crystal oscillators. If the divider is fed from a low-voltage transistorized stabilizer the divider phase instability will be almost zero with supply voltage variations.

4. Total phase variations in the divider circuit components for temperature changes between 20 and 65°C result in phase differences between the input and output voltage amounting to 6-8 μsec.

In regenerative frequency dividers it is possible to use at one of the intermediate frequencies (50 to 10 kc) a phase shifter required for altering or reestablishing quartz-clock readings. In transistorized divider circuits it is advisable to use induction phase shifters, which have low input and output impedances and hence are easy to match to the transistor circuits. In the above divider we used a miniature phase shifter at 10 kc. The 10 kc voltage is fed from the secondary winding of tuned circuit L_6 to the phase shifter. From the phase shifter the voltage is fed to the transistor base of the tuned amplifier which forms part of the second decade. From the secondary winding of this amplifier's tuned circuit the 10 kc voltage is fed to the balanced modulator of the following decade divider which is similar to that shown in the figure attached.

The phase shifter dimensions are 50 x 50 x 20 mm. The transmitting and receiving induction coils are wound on halves of the SB-1a cores with 1000 turns of 0.05 mm PÉL wire on each. A slotted permalloy disc mounted on the phase shifter spindle is used as a baffle.

The stray amplitude modulation of the voltage at the output of the phase shifter does not exceed 20-30%. The voltage transfer constant is equal to 0.5. The same phase shifter can be used at a frequency of 1 kc. The voltage transfer constant at that frequency is lowered to 0.014-0.020.

A further frequency division from 1 kc to 1 cps can be carried out by mechanical means with a synchronous motor or by means of electronic circuits. The best results with respect to stability, reliability and economy of operation are attained by using transistor scaling circuits.

SUMMARY

Regenerative transistorized frequency dividers have a highly-stable phase characteristic with the supply voltage and ambient temperature varying over wide ranges. The above divider is not inferior in its phase stability to highly stable tube frequency dividers.

The use of transistors and miniature components makes it possible to produce economical, reliable and small frequency dividers for quartz clocks. The lower power consumption of transistorized dividers makes it possible to feed them from storage batteries of a relatively small capacity.

In transistorized circuits it is advisable to use inductive phase shifters for varying the quartz-clock readings.

From the editorial board. Although the above regenerative frequency dividers when used in quartz clocks are inferior with respect to accuracy and reliability to binary scaling circuits, their application in many cases is justified because of their simplicity and good signal waveform.

PROPORTIONAL COUNTERS USING COMMERCIAL EQUIPMENT

A. F. Vinogradov, L. I. Chigarev, and S. P. Rybak

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The use of proportional counters with a constantly flowing working gas for measuring α and β radiations have certain advantages as compared with Geiger-Mueller and scintillation counters. Their operation is stable with less pure gases, they have a higher resolution than the Geiger-Mueller counters, they are affected less by γ-radiations than the scintillation β-counters.

This article deals with several methods of utilizing proportional counters of different constructions in conjunction with commercial computing apparatus.

A 4π counter used with a PS-10000 instrument. The 4π counter [1] is used in a proportional counting condition with instrument PS-10000. The negative pulses of the counter are amplified and fed to the input of the computer. The counter is supplied with 3200 v from a high-voltage battery which is mounted on a metallic jacket-screen and consists of four sections with three GB-300 batteries in each. The type GB-300 batteries are placed on insulating block stands and fixed together with clamping pins. The high voltage is connected and disconnected by means of plugs. From the batteries the high voltage is supplied by means of cables. The amplifier circuit is similar to that of an ISS amplifier counting-rate meter. The input circuit of the amplifier is changed in the manner of its switching to the counter. In this connection attention sould be paid to the isolating capacitor in the first stage grid circuit. The capacitor insulation must be very high, otherwise false pulses are produced which are added to the background of the counter. This requirement is met by capacitor type POV of 390 $\mu\mu f$ and 15 kv.

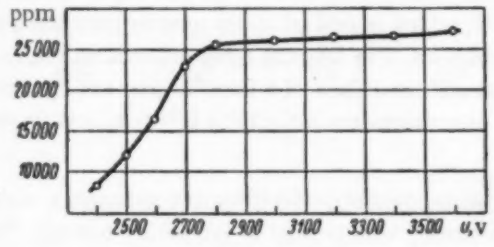

Fig. 1.

Since the amplifier consumption is small it is fed from the type PP power pack of the POS-10000 set. The working gas is made to flow slowly and continuously through the counter. Instead of pure methane we used the gas from the Moscow mains. From the mains the gas is taken through a calcium chloride dessicator to the counter and on leaving it is burnt on a low-intensity table laboratory burner. The adaptor flange should be sealed by means of an additional device fixed to the body of the counter. The characteristic of a counter operating on the Moscow mains gas was measured by means of a "soft" β-radiation (Fig. 1). The working voltage of 3200 v was chosen according to that characteristic.

Proportional counter SP-3 for instrument PS-10000. 4π counters require special preparation of the tested sample [1], hence they are unsuitable for mass laboratory measurements, and their construction does not permit their use with PS-10000 instruments. The authors of this article have made, for using with the PS-10000 instrument, a proportional counter SP-3 which provides α-and β-activity measurements with a highly effective count by means of ordinary "targets" used with butt counters.

Proportional counter SP-3 (Fig. 2) has a cylindrical nickel-plated brass cathode 1. Two connecting pipes 2 are soldered to the upper part of the cathode, one of which is connected to the gas supply, and the other serves as an outlet for the gas. Contacts 3 and 4, which carry a tungsten or molybdenum 20 to 40 μ filament, are mounted on two insulators below the aforesaid pipes.

Contact 3 is connected to an extension-piece 5, which has a jack for the recording device plug. Insulator 6 made of plexiglas components has a guard ring 7. The counter cathode is held between two plexiglas plates 8 with rubber packing.

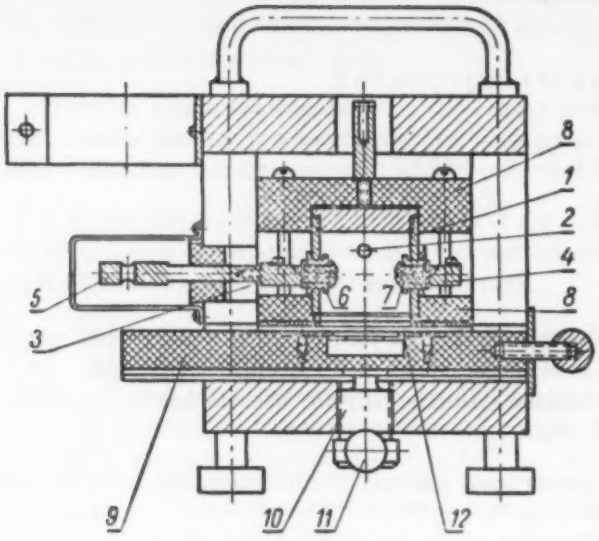

Fig. 2.

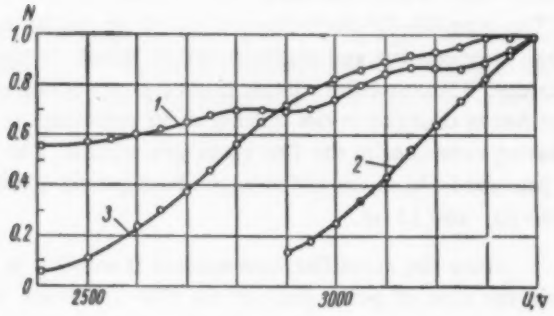

Fig. 3.

Cell 9, which carries the measured sample, is made of perspex. When the cell is inserted or withdrawn the sealing is made by means of a device consisting of screw 10, handle 11 and rubber packing. The cell carries a nickel-plated brass plate 12 with a socket for the measured sample. When the cell is inserted plate 12 is connected by means of contacts to the counter cathode. The characteristics of counter SP-3 are shown in Fig. 3. Curves 1 and 2 characterize the measured α-and β-radiations when the Moscow mains gas flows through the gas-meter. Curve 3 corresponds to measurements of β-radiations when a mixture of methane and argon in the ratio of 1:1 is made to flow through the meter. It will be seen from these characteristics that for counting α-particles (curve 1) the high-tension power pack of the instrument can provide the required voltage. In counting β-particles the operating counter voltage is higher than the high-tension power pack is capable of providing; hence a boosting voltage consisting of one or two GB-400-0.01 batteries is provided. The SP-3 counter is connected to instrument PS-10000 by means of an extension cathode follower. The booster battery pack consists of a steel box which carries two flat batteries type GB-400-0.01 contained in a plexiglas jacket. The batteries are connected to counter SP-3 in series with the high-tension source of the PS-10000 set by means of plug-type connectors and coaxial cables. For a gas flow through the meter amounting to 1.5 to 24 liter/hr, the counting efficiency remains practically constant, only depending on the chosen operating voltage. With an appropriate operating counter voltage the counting efficiency for soft radiators amounts to 30-40%, which is several times greater than the efficiency of butt counters. The flushing time depends on the speed of the gas and for a flow of 5 liter/hr does not exceed 30 sec. The electrical capacity of the counter is 8.5 $\mu\mu f$. Its over-all dimensions are 120 x 120 x 180 mm, and its weight is 12.5 kg.

TISS radiometer with a proportional β-counter. For checking surface polution by β-active substances, radiometer TISS in combination with the extension transducer TCh is now being widely used in laboratory testing. Three STS-6 counters with steel cathodes are used as detectors in the TCh transducer. The efficiency of recording pollutions by β-active substances with a low energy radiation by means of this unit will be extremely small, owing to the thickness of the counter walls. For instance, it is practically impossible to record pollutions by promethium-147, sulfur-35 or carbon-14. For such measurements it is possible to adopt the TYu unit which is intended for checking pollutions of large areas by α-active substances and is equipped with a proprotional air-filled counter which has a thin (0.3-1.0 mg/cm^2) terylene film window. The required gas amplification in the proportional counter is obtained by supplying it with the required high voltage. The high voltage value required for registering β-particles is beyond the range of the TISS instrument. The use of a sufficiently high voltage makes the air-filled counter operate in a permanent discharge condition. The recording of β-particles becomes possible if the air filling of the TYu unit is replaced by a flow of a working gas which provides the required gas amplification coefficient at lower operating values of the voltage. The Moscow mains gas was used for this purpose. Thus, a stable and reliable operation of the TYu unit proportional counter was attained in recording β-particles.

The required high voltage is in the range of 2000-2100 v. The highest obtainable voltage in the TISS set amounts to 2000 v. Hence, an additional miniature battery GB-400-0.01 had to be used. The use of a booster battery provides the required high voltage range, improved stability and smooth setting of the working voltage. The constructional changes required in the TYu unit are small. Two pipes serving as an inlet and an outlet for the gas were screwed

into the main body of the unit and sealed by means of vacuum rubber washers 3 mm thick. In order to obtain hermetic sealing, the safety grating with its vacuum rubber packing at the edges is pressed against the body of the counter by means of screws. The booster battery is placed in the amplifier compartment of the TYu unit by replacing its bottom lid with a deeper one.

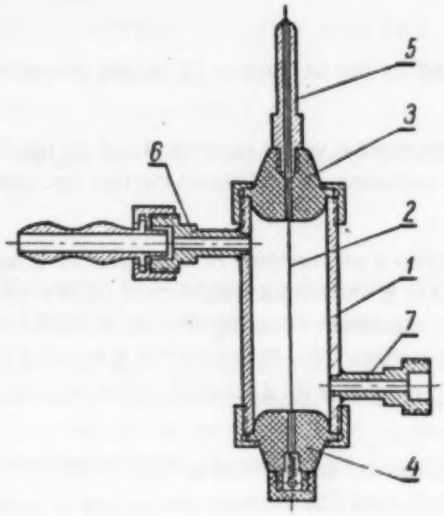

Fig. 4.

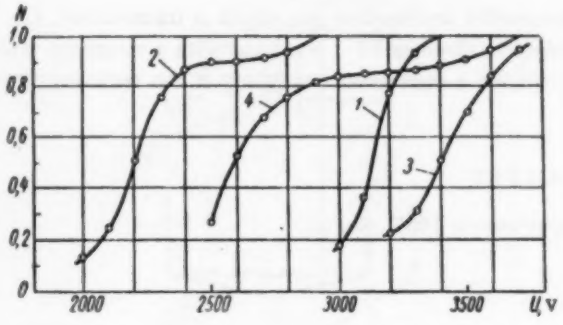

Fig. 5.

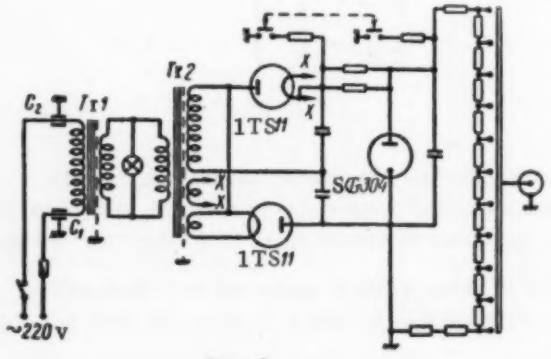

Fig. 6.

The modified TYu unit can be used for measuring β-particles of sulfur-35, promethium-147 and other soft β-radiators.

Recording radioactive gas by means of a proportional flow counter SP-1 and an ISS instrument. For recording α and β-active gas we also used a proportional counter. The radioactive gas in a proportion established experimentally is added to the basic working gas of the counter. Methane is mainly used as the operating gas, since it provides the most extensive volt-ampere characteristic for the counter. The gas mixture is fed inside the counter. The counter pulses are fed through an extension cathode follower to the counting rate meter ISS, to whose output the ĖPP-09 recorder is connected.

Proportional counter SP-1 for measuring radioactivity in gas (Fig. 4) consists of a nickel-plated brass cathode 1 with a polished internal surface, and a tungsten or molybdenum 20 to 40 μ filament 2, mounted on insulators 3 and 4. For operation at room temperature the insulators are made by plexiglas for temperatures up to 200°C they are made of teflon. The counter is connected by means of plug 5 to the electronic recording device. The counter casing 1 is connected to the body of the electronic recording device. The gas is supplied through pipes 6 and 7. The counter volume amounts to 8 cm^3. Figure 5 shows SP-1 counter characteristics for various gases and gas mixtures. The counter operating voltage U is plotted along the X axis, and the relative rate of counting N along the Y axis. The characteristics were obtained with an external radioactive source with a mean rate of count totaling 50,000 pulses per min. Curve 1 represents the operation of the counter with pure methane; curve 2 with a mixture of methane and argon in the proportion of 1:1; curve 3 with carbon dioxide; curve 4 with a mixture of carbon dioxide and argon in the proportion of 1:1. It will be seen from these curves that the most extended segment of the characteristic is obtained with methane. It also makes it possible to use a high-tension power pack with a relatively low voltage stabilization. The addition of argon to the gas mixture provides a lower operating voltage; however, the characteristic then becomes more slanting. When gases are used which do not provide the horizontal part of the characteristic, an increased stability of the high-voltage supply is required. We used a high-voltage source arranged in a circuit shown in Fig. 5. The high voltage supplied by transformer Tr2 is rectified in a voltage doubling circuit by means of ITs11 kenatron rectifiers. The voltage is stabilized with an SG-304 gas-discharge stabilizer.

The stabilized output voltage can be changed in steps of 50 v in the range of 2.8-3.3 kv. The primary winding of the high-tension transformer Tr2 is fed from the low voltage winding of transformer Tr1 with 6-7v. Such a

supply circuit, screens between the windings and capacitors C_1 and C_2 reduce considerability the pulse interference from the mains.

The counter is connected to the extension stage in a manner similar to that previously described.

SUMMARY

1. The use of the Moscow mains gas for the above counters and for the 4π counter [1] makes proportional flow counters more practical and easier to operate.

2. When the gas is burnt on ordinary laboratory burners its consumption varies between 4 and 25 liter/hr. Since the efficiency of counting remains practically constant despite this variation, no additional devices for controlling the gas flow are required.

3. For the standard instrument PS-10000 produced by our industry a proportional flow counter SP-3 has been designed and constructed. The counter is intended for measuring α-and β-radiations with normal targets which are used in the operation of butt counters. It can also be used with other electronic counting devices which have the required pulse amplifier and a source of high tension with a grounded positive side. Counter SP-3 is superior in its basic operating characteristics (in a stationary condition) to the butt counters with a window and to α- and β-scintillation counters; moreover, its construction is much simpler.

4. For measuring α- and β-radioactive radiations the TISS instrument is used with a slightly altered TYu unit, as a result of which it becomes possible to measure low energy β-radiations (the counter window has an area of 150 cm^2 with a transparency up to 0.3 mg/cm^2). Moreover, the TISS instrument also acquires a new valuable property, namely it can measure pollutions by such isotopes as sulfur-35, promethium-147, carbon-14, and others.

5. Counter SP-1 has been designed and constructed for measuring radioactive gas which is transmitted, for instance, from a radiochromatograph column, or for similar purposes. Counter SP-1 was used with a counting-rate meter type ISS and a recording potentiometer ÉPP-09, which provided a continuous recording of the radioactivity of the measured gas with a high efficiency of counting.

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METERING VESSELS IN STATIONARY TEST INSTALLATIONS FOR VOLUMETRIC LIQUID METERS

A. N. Pavlovskii

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The article reviews certain metering vessels used in the USSR and abroad in stationary test installations for meters of noncorrosive liquids.

Basic, far from exhaustive, information on metering vessels in test installations for oil product meters is given in instruction 30-55 on checking reference metering vessels. In a more complete form this information is provided in operational instructions for checking oil product meters and their testing equipment. These instructions provide schematics of the metering vessels and specify requirements both for them and their test equipment.

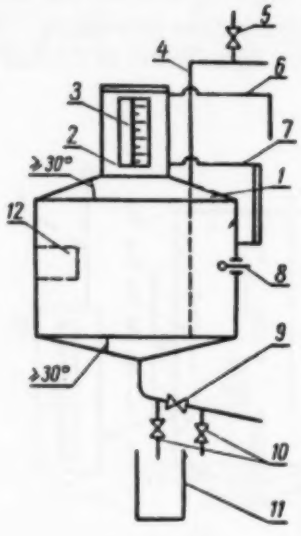

Fig. 1.

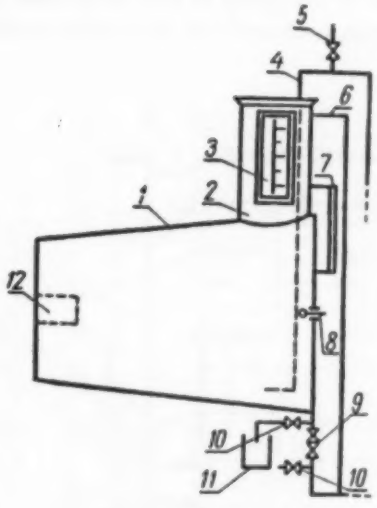

Fig. 2.

Figure 1 shows the schematic of a metering vessel of a test equipment for oil product meters. The metering vessel is made in the form of a reference 2nd grade vessel. Metering vessels of a capacity exceeding 2000 liters can be made in the form of 1st grade technical metering vessels with a horizontal or sloping axis (Fig. 2).

The body 1 of the vessel is made either in the form of a cylinder terminating in cones at both ends (see Fig. 1) or in the form of a truncated cone with a horizontal axis (see Fig. 2), or else as a cylinder with a sloping axis.

The walls of the upper and lower cones of the vessel (see Fig. 1) make an angle of at least 30° with the horizontal. The same slope angle is maintained for the walls of conical vessels (see Fig. 2) and the axes of cylindrical sloping vessels.

Neck 2 of all the metering vessels meets the requirements of 2nd grade vessels with respect to its cross section and volume. The cross section of the neck was chosen so that a level difference of 6 mm corresponds to 0.1% change in the volume of the vessel. The volume of the neck within the range visible through the inspection window 3 amounts to not less than 4% of the vessel's volume. The vessel's neck is fitted with two diametrically opposite windows. One of the window frames is fitted with a calibrated scale which shows the amount of liquid in the metering vessel.

The metering vessel necks in installations used for testing gasoline meters and other volatile liquid meters are hermetically sealed with a lid. The air and vapor of the liquids are brought out through valves or pipe 6 which connects the vessel with the storage tank or the atmosphere outside the premises. These pipes are often used for transferring the liquid. Pipe 4 which brings the liquid from the meter comes down inside the vessel almost to the level of the lower cone, and is fitted in its upper part with an air valve 5 or a tap, thus ensuring a constant level of the liquid in the pipe before and after pumping.

The metering vessel is emptied through the drainage tap 9. The completeness of draining and the sealing-off by the drainage tap are controlled by means of taps 10 through which the remnants of the liquid are poured into a portable tare contained 11.

The filling of the metering vessel is checked through the glass level gauge tube 7.

If necessary the metering vessel volume is adjusted to its nominal value by compensator 12, whose volume is determined when the vessel is calibrated.

The temperature of the liquid is measured in vessels smaller than 500 liters with one thermometer 8, and by means of two thermometers in vessels exceeding 500 liters. Thermometers with calibrations of 0.1°C are used for this purpose. Instead of thermometers other temperature measuring devices can be used, providing they meet the requirements with respect to accuracy and safety.

The basic data used for selecting the volume of the metering vessels consist of the minimum time required for checking meters at a maximum flow and the characteristics of the tested meters' reading indicators. The volume of the metering vessel must not be less than the larger of the two volumes, consisting of either the volume of the liquid measured by the meter in five revolutions of its counting indicator large pointer (500 smallest calibrations of the roller counting indicator), or the volume of the liquid flowing through the tested meter in 1.5 min at a maximum tested flow.

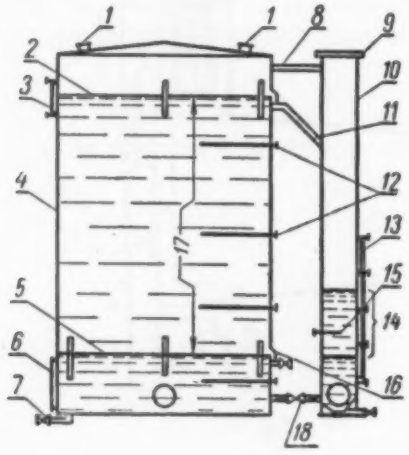

Fig. 3. 1) Air inlet 200 mm pipes; 2) overflow level; 3) four level-measuring tubes; 4) fixed volume cavity; 5) zero level; 6) inspection hatch; 7) drainage tap; 8) air equalizing pipe; 9) removal lid; 10) small measuring tank; 11) overflow threshold pipe; 12) four thermometers; 13) level-indicating glass tube with a scale; 14) volume of the overflow liquid; 15) thermometer; 16) decanting device with a drainage pipe; 17) fixed volume; 18) equalizing pipe with a valve.

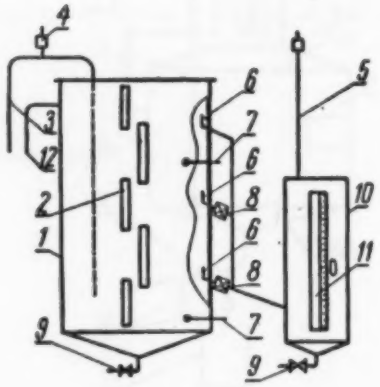

Fig. 4.

The error of the metering vessels does not exceed ± 0.1% of their nominal volume.

Recently new metering vessels have come into use, which have no neck, but use instead a cylindrical tank of a small cross section placed side by side with the main vessel.

Figure 3 shows a schematic of such a metering vessel 61 m^3 in volume for checking large flow meters. Such a meter has been installed at one of the US oilfields. It consists of a large open tank 3.8 m in diameter and 6 m high, and of a small tank 650 mm in diameter and 6 m high, which serves as a lowered neck of the large tank. The tanks are interconnected by two decanting devices which consist of horizontal thresholds with pockets terminating in drainage pipes. The thresholds have bevelled edges. The volume of the liquid contained between the threshold edges of the large tank is fixed precisely and the effect of surface tension on that volume is eliminated. The small

tank is fitted with a level-measuring tube and a scale. The scale is calibrated with the volume of the large tank taken into account, so that it indicates the total volume of liquid contained in both metering vessels.

The above metering vessel arrangement in a slightly modified form is used in an experimental installation of the "Nefteismeritel' " plant. The large tank 1 of the metering vessel (Fig. 4) has three overflow pockets and hence three drainage pipes. The pipes are fitted with valves 8 with pneumatic drives. The large tank has three fixed levels limited in their lower part by the drainage device 9 and in the upper part by the levels of thresholds 6. The small tank 10 is fitted with an inspection window 11 whose frame contains a calibrated scale. Approximately in its middle the scale is marked with the nominal volume, which serves all the three fixed volumes of the large tank. Calibrations in an increasing order are placed above and below this mark.

The small tank performs the function of a metering vessel neck and the relevant requirements of instruction 30-55 apply to it both with respect to its volume and cross section. Its volume within the visible part of the inspection window is not less than 4% of the largest fixed volume of the vessel, and its cross section provides that a level difference of 6 mm amounts to no more than 0.1% of the smallest fixed volume in the large tank.

The inlet pipe 3 has in its upper point an air escape valve 4. The air from the tank is released through pipe 5 and the air escape valve. The temperature is measured with thermometer 7. The filling of the tank is observed through inspection window 2. The overflow is taken by pipe 12. When testing meters at their maximum flow the volume up to threshold 6 of the top overflow pocket is used, and when testing them at their minimum flow the volume up to threshold 6 of the lower overflow pocket is used.

In order to eliminate the effect of surface tension, the height of the volume up to the threshold edge of the lower pocket must be not less than 1000 mm.

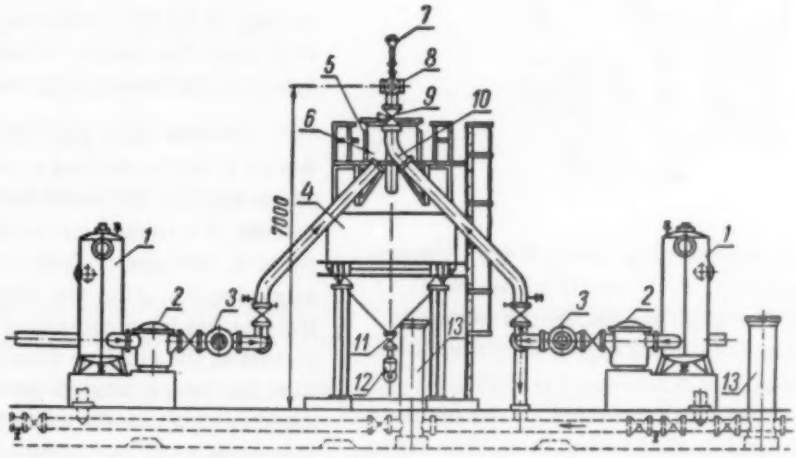

Fig. 5.

Figure 5 shows the testing installation used in Germany for checking meters with a caliber up to 300 mm used for gasoline and diesel oil. In the operation of this installation the liquid passes consecutively through a pulsation damper 13, air separator 1, filter 2, counter 3, inlet pipe with a turning elbow 10, control tap 9 and leads out into a hermetically sealed metering vessel 4 with a volume of 50 m^3.

The calibrations are read off the scale placed in the inspection window 5. The cross section of the neck 6 is based on the condition that its level differences of 10-20 mm correspond to not more than 0.1% of the metering vessel volume. The vessel is emptied through gate valve 11, immediately below which the inspection window 12 and tap are placed. Through this window it is possible to observe the completeness of drainage of the vessel before checking the meter. The tap serves to check the hermetic closing of the vessel during filling.

The highest point of the supply pipeline is fitted with an inspection port 8 and valve 7 for supplying air to the tube after filling the vessel. The inspection port serves to check the constancy of the level before and after the flow of the liquid.

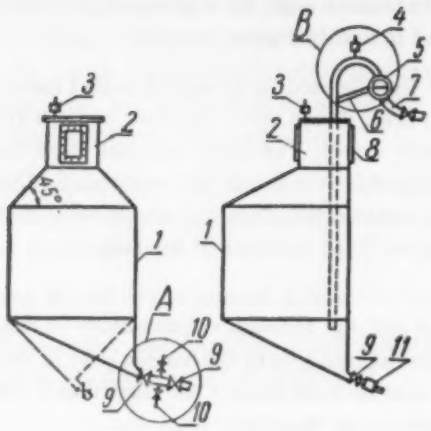

Fig. 6.

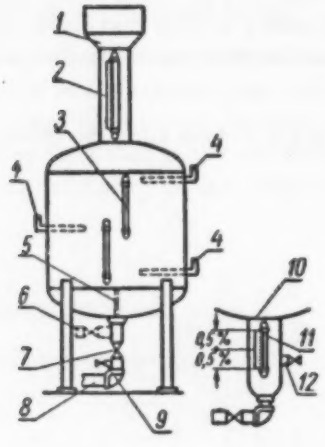

Fig. 7. 1) Funnel; 2) inserted glass scale; 3) sight glasses; 4) thermometers spaced by 120° and 1/3 of the vessel diameter in length; 5) a plate preventing the formation of an eddy in the liquid; 6) liquid supply from the bottom 7) drainage valve (must be in a vertical position); 8) drainage pipe; 9) control tap; 10) device for the metering vessel bottom (version); 11) bottom set-in glass scale; 12) tap for checking the metering vessel.

Figure 6 shows the schematic of the metering vessels used in the French test installations.

Neck 2 of metering vessel 1 is covered with a lid which has an air outlet valve 3. The neck is fitted with two inspection windows 8. The nominal volume mark is placed in the middle of the inspection windows. The volume of the neck in the limits of the inspection window visibility amounts to 2% of the nominal vessel volume. The neck diameter meets the condition that neck level differences of 5 to 2 mm correspond to 0.1% of the nominal volume of 100 to 1000-liter metering vessels. The vessel volume amounts to 1/20-1/30 of the nominal hourly flow of the tested meter and must amount to not less than the volume corresponding to 500 smallest calibrations of the measured meter scale. The error of the vessel is ±0.02-0.05% of its nominal volume.

The lower cone of the vessel is fitted with one or two drainage taps 9. In the first case in order to check the hermetic sealing of the tap, the drainage pipe is fitted with a transparent cylinder 11. In the second case the metering vessel is supplied with device A consisting of two drainage taps 9 placed one after the other, but separated by a short pipe which has two vertically placed taps 10 fitted to it. In this case the hermetical sealing of the first (main) tap is checked by opening both taps. The absence of any discharge through the lower tap indicates satisfactory sealing.

In their upper part the vessels are equipped with device B which provides a constant level in pipe 7, which supplies the liquid from the meter. The device consists of a transparent inspection port 5, an air supply valve 4, and pipe 6 which shunts the upper part of the inlet pipeline. After the flowing of the liquid through the pipe has been completed air is admitted to the upper portion of the pipeline through valve 4, and the liquid from the pipe section in the bend flows through the shunting pipe into the metering vessel, thus providing a constant level in the inspection port.

Both open and closed metering vessels are used in the USA for checking oil product meters. Open vessels (Fig. 7) are used for checking meters of nonvolatile liquids, and the closed vessels when it is necessary to prevent losses through the evaporation of the liquid.

The measuring volume of the metering vessel is selected on the basis of its containing the liquid supplied to it during 1.5-2 min when the meter is tested at its maximum flow.

The volume of the neck from the lower mark of the scale to its top amounts to 4%, and the section visible through the inspection window to 2% of the nominal metering vessel volume. A 15 mm height of the neck section corresponds to not more than 0.1% of the nominal vessel volume. However, in all cases the vessel neck has a diameter not less than 75 mm.

The necks of open metering vessels are connected to funnels. The vessel scales are calibrated in percentages, cubic centimeters or the measuring units used in the meters.

The enclosed metering vessel has two necks, a top and a bottom one. The measuring volume of the vessel is set on scales fixed to inspection windows in the necks.

The metering vessel can be filled either from the top or the bottom. The internal surface of the vessel is wetted by the measured liquid before checking the meters.

The temperature of the liquid is measured by means of thermometers placed at different levels and at an angle to each other.

Volume meters are often supplied with flowmeter attachments for checking and controlling the flow of the liquid. Metering vessels for checking such meters must, therefore, be equipped to check both the volume meters and their flowmeter attachments. The latter may be achieved by means of metering vessels shown in Figs. 3 and 4 if they are fitted with inspection windows (one or several staggered windows) and scales to fit in them. In the simplest case the flow is determined by the time required to fill a volume between set markings of the scale. For the same purpose the metering vessels can be supplied with equipment for switching the flow into the drainage part (pipe) before and after the test flow period. The switching device is coupled to instruments for measuring the time required to fill the metering vessel.

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CONTINUOUS MEASURING OF THE HEIGHT OF COAL FITTING BY MEANS OF RADIOACTIVE ISOTOPES*

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 56-57, May, 1961

Electrical power stations require a unified equipment for checking and controlling the filling of coal hoppers, since their uniform filling by coal is an important factor in production automation.

The measuring system must satisfy several requirements. It must be suitable for the coal hopper supply system, the varying coal characteristics (moisture content, temperature and the size of pieces), must not affect the accuracy and constancy of measurements, the information on the amount of coal in the hopper and its level must be easy to process, the system must be simple in its design, easy to install, have a long life and must lower maintenance expenses.

The above instrument operates on the principle of measuring by means of radioactive isotopes and is based on the different absorption of radiations by coal and air owing to the difference in their specific gravities (see figure).

When the radiation source and detector, which are placed in steel pipes, are at the level of the coal surface, their displacement system is disconnected. In this case the compensating regulator 4 is also disconnected. When the coal surface rises above the detector, the radiations have to pass a layer of coal which absorbs them. This generates a signal in the radiation intensity meter 3, which unbalances the regulator, and switches-in the electric motor. This operation will persist until the radiation source and detector are brought into a new balanced position corresponding to the coal level. The equipment can work with an error of ±1 cm, however, such an accuracy is not required in controlling production.

The compensation regulator may be replaced by a microrelay, electronic regulator, etc.

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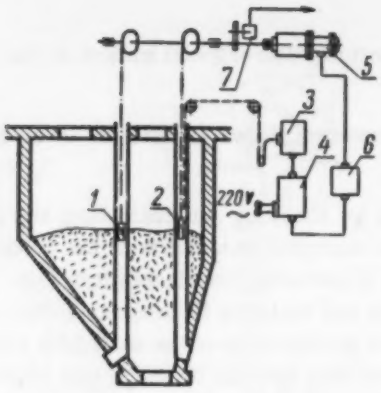
*Abstract of article by P. Hudec and P. Schiller, Kontinuaine meranie výšky nàsypu uhlia radioizotopmi. From the Czechoslovak journal "Automatizace," 1961, No. 1.



1) Source of radioactive radiations; 2) detector; 3) radiation intensity meter; 4) compensating regulator; 5) electric motor; 6) remote control of the "radiator-detector" system; 7) information transmitter consisting of a variable resistance.

The motor is coupled to a transducer, such as a variable resistor, which transmits the information on the position of the source-detector system to a monitoring or controlling device. Information can be transmitted by other means, for instance, by a pulse device, and induction transmitter, etc.

The electromechanical drive is fitted with contacts which disconnect the motor in the highest and lowest positions.

The device can be used for detecting free spaces, so-called holes in the lower part of the hopper. The formation of a hole may cuase an interrupted supply of fuel to the crushing machine.

The detection of holes by the above device is carried out in the following manner: the person exercising the remote control of the radiator-detector system moves it inside the tubes along the whole height of the hopper. If a hole is encountered between the radiator and detector the absorption of radiations decreases, and this is registered by a special monitoring instrument. The place and height of the hole can be gauged from the scale of the profile monitoring device. In future the instrument will be supplied with an automatic indicator of holes. For this purpose the measuring system will be supplemented with a clockwork programming device, which at definite time intervals will disconnect the regulator and connect the motor. The latter will move the radiator-detector system along the whole height of the hopper. A visual or audible signal will indicate the location of a hole.

Isotope Co^{60} with an activity of 3 mC is used as a radiation source. The above isotope makes it possible to work with steel pipes separated by 75 cm. In case of necessity this distance can be increased considerably. Radiations were recorded on a halogen-filled Geiger-Mueller radiation intensity meter.

The above instrument ensures complete safety of the operating personnel from radioactive radiations.

HALL TRANSDUCER INSTRUMENT FOR MEASURING MAGNETIC FIELDS*

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 57-58, May, 1961

The firm of Siemens u. Halske (FGR) manufactures a portable miniature instrument for measuring dc magnetic field strengths, based on the Hall effect in semiconductors. As compared with existing instruments used for this purpose, such as fluxmeters, measuring generators and instruments with bismuth spirals, the new meter has several advantages.

The measured quantity is converted by the Hall transducer into a dc voltage measured on a sensitive moving coil instrument.

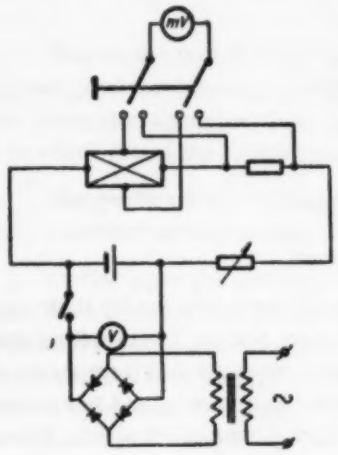
The reading is obtained from a static deflection of the instrument pointer, with the probe remaining in a stationary position.

The effective surface of the measuring probe is extremely small (2 x 2 mm), which makes measurements of nonuniform magnetic fields possible.

*Abstract of the article "Ein Magnetfeldmessgerät mit Hallsonde". Z. für Instrumentenkunde, 1960, No. 8

The instrument measures polarity and the direction of the field as well as changes with time of the measured field.

The circuit of the instrument is shown in the figure attached. The Hall transducer is made of indium arsenide. Its over-all dimensions in a protective jacket are 12 x 4 x 1 mm. The control current is supplied by a 1.2 v storage battery which is incorporated in the set and provides its continuous operation for 12-15 hr. Facilities are provided for charging the battery through a rectifier from 220 and 110 v mains.



The transducer's control current is evaluated by measuring the voltage drop across a reference resistor in the control circuit. For this purpose the same millivoltmeter is used which measures Hall's emf. The control current is adjusted by means of a variable resistance whose control knob is mounted on the top panel of the instrument.

The millivoltmeter has a treble scale. The instrument's measuring ranges are 0.5-1-2-5-10-20 koe. The ranges are switched by changing the control current.

The instrument's error does not exceed ±1.5% on any of the ranges.

The sensitivity of the instrument can be raised by using a magnetic field concentrator. Under this condition the 500 oe scale of the instrument will correspond to 10 oe.

The concentrator is made in the form of permalloy rods in whose air gap the Hall transducer is inserted. The total length of the concentrator is 150 mm. It is especially advisable to use the concentrator in the neighbourhood of busbars through which a heavy current is flowing.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

NEW PRINCIPLES FOR DETERMINING COMPULSORY STATE TESTING OF MEASURING INSTRUMENTS

(Comments on V. D. Alesin's article*)

B. N. Vorontsov
Deputy Head of the Gor'kii Automobile Plant TsIL (Central Test Laboratory)

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 58-61, May, 1961

B. D. Alesin's article raises important questions of organizing measurement work.

Com. Alesin's proposals on determining compulsory testing of instruments not by their type but by their application is completely right. Each plant should establish a list of instruments subject to state testing. In compiling this list the following considerations should be taken into account: All reference (primary) measures and instruments should be subject to state testing, as well as instruments which cannot be tested at the plant; instruments used in accounting operations, in trade, in health protection, etc., and those on the special list of the Committee of Standards, Measures and Measuring Instruments. All other instruments should be checked by the service inspection agencies of the plant, and in heavy inspections selective checking should be allowed.

As far as state inspection is concerned of such measuring equipment as sorting and checking automatic machines, and means of continuous and other automatic control, it is impossible to agree with Alesin's opinion. In order to determine the measurement errors in automatic control devices it will be necessary to establish numerous standards and special techniques for checking each equipment separately. Even if we assume that the GKL (State Inspection Laboratory) possesses the required equipment and techniques for testing automatic control machines, their checking at long intervals (1-2 years) will in practice be useless, since their operation should be checked every day, which is only within the scope of service inspection agencies. The GKLs should only supervise the service inspection agencies which service, adjust and repair the automatic control machines. Checking that the automatic control equipment readings are accurate and that they meet the technological production requirements should be made to coincide with heavy inspections of the service agencies.

In the second half of his article com. Alesin in fact suggests that the GKLs should be turned into area experimental-research laboratories capable of dealing with all the problems which arise at the plants in connection with technical measurements. If one compares the actual state of the GKL control and testing equipment, which in many instances is below the present requirements of our national economy, with the varied problems which require immediate solution, it will have to be admitted that such a reorganization will in the next few years be beyond the capacity of the Committee of Standards, Measures and Measuring Instruments.

It is advisable to make such area organizations operate under the guidance of the councils' of national economy scientific research institutes, which have the highly qualified experts capable of dealing with all the technological production problems.

The functions of the GKLs should, under these conditions, be limited to checking reference (primary) measures and instruments, whose lists should be established by the Committee. All the remaining organizational and technical work, including the enforcement of standards and the specified service inspection, should be entrusted to the experimental-research area laboratories of the councils of national economy. The adequate technical equipment of the latter will make it possible to catch up in the shortest possible time the lagging of the measurement equipment behind the requirements of production automation.

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*Izmeritel'naya tekhnika 1960, No. 10.

E. L. Perel'shtein
Head of a plant KIP (Control and Measuring Instruments)
Laboratory

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 59-60, May, 1961

Despite the fact that the majority of plants, scientific research institutes and design organizations have at their disposal good test laboratories registered by the Committee of Standards, Measures and Measuring Instruments as service inspection agencies, there exists an urgent necessity for speeding up the solution of certain organizational questions which retard the development of laboratories and lower the technological possibilities of production.

The publication of the regulation on central laboratories for measurement equipment in plants has clarified many questions related to their activity.

At first sight the problems raised by V. D. Alesin's article have no relation with the operation of plant laboratories for measuring equipment; however, this is far from being the case. For instance, the suggestion that the activity of the service inspection agencies should be limited to checking nonessential measuring equipment is amazing. Perhaps com. Alesin is worried about the qualifications of inspectors, the equipment, basic means of inspection, premises, or some other considerations? It appears to us that the existing heavy inspection services in the Committee's system are capable of dealing effectively with these problems during heavy inspections, and of ensuring the high technical efficiency of measures and measuring instruments under their operating conditions.

The mere classification of the measuring equipment into essential and nonessential for a given production process will bring confusion into the work of the service inspection agencies as well as the heavy inspection services of the Committee.

Moreover, it is not clear from the article who is to be in charge of compiling the list of instruments used in especially essential production processes, whether it is to be the Committee's technical inspector or the personnel of the service agencies? It seems to be illogical, on the one hand, to deprive the service agencies of the right to check essential instruments, and on the other to entrust them with deciding which instruments they will check independently and which will have to be presented for state inspection.

V. D. Alesin's proposals may also involve the state in excessive expenditure, since they will require additional experts, equipment, reference instruments and installations, there will be a rise in the expenditure on transporting instruments, heavy inspections, etc. As a result of this the reliability of the measuring equipment instead of improving may actually deteriorate, for instance, in the case of transported instruments, and it will reduce the efficiency in solving production problems.

There exists an opinion that is is much cheaper to maintain a single repair and inspection laboratory for any administration, district or city, since, it is claimed, that the equipment, instruments, and experts can be more fully utilized. But this opinion is incorrect for many reasons. Firstly, the efficiency in servicing production needs will be reduced and production will be deprived of especially precise measuring equipment. Secondly, there will be no point in a plant maintaining technical personnel for precision measurements and inspection of its stock of measuring apparatus, in having reference instruments and at the same time spending money on the repair and checking of instruments by outside organizations. Moreover, it is very doubtful whether it is correct to claim that without external services for checking and repairing instruments it is impossible even with appropriate inspection to ensure an efficient technical condition for measuring equipment.

It should also be remembered that the laboratories for measuring equipment serve to introduce new instruments into the plants, to help the production personnel in solving certain complex problems, in training workers, engineers and technicians in the use of the new equipment, etc.

This is why an all-around improvement in the measuring equipment laboratories at each plant is a task of outstanding importance for the state.

Yu. Ya. Donde, Head of the Inspection and Test Laboratory
of an Electric Bulb Plant

Z. I. Druker, Head of the Electrical Measurements Laboratory
of the S. M. Kirov DYNAMO Plant

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 60, May, 1961

We are bound to agree with certain propositions made in V. D. Alesin's article. For instance, we agree that the inspection of all the measuring instruments should be divided into state (compulsory by the Committee's agencies) and service inspections, and that the compulsory inspection should be determined not so much by the type of instrument as by its application. Moreover, the plants should have the possibility of completely cancelling the checking of certain instruments when they are used merely as indicators and do not require any accuracy in their readings. This would relieve plants from unnecessary, sometimes completely senseless work.

We also approve of the proposal that service inspection should be made both according to the Committee's instructions, and by means of the equipment provided by the plants according to their own methods.

However, we should like to make certain reservations from the point of view of factory test laboratories. For instance, taking into consideration the improved work of the service inspection agencies, their increased personnel, and their provision with reference equipment, we think it advisable to reduce still further the list of instruments subject to state testing. State testing, in our opinion, should only apply to primary (reference) measures and instruments to instruments used in trading or state deliveries, and in measuring energy consumption which has to be paid for. But we reject categorically state inspection of instruments used in essential production processes, in checking finished articles by the OTK (Technical Control Divisions) and in all similar cases, since the quality of the testing carried out by the service inspection agencies in the majority of cases is no lower than that obtaining in state testing, which complicates the work of plants, makes checking more expensive, and in the long run only leads to increased costs of production. The introduction of state inspection in such instances also makes the service inspection agencies redundant.

Extracts from the Proceedings of the conference called by the Novgorod GKL (State Inspection Laboratory) of Measuring Equipment

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 60, May, 1961

In February, 1961, V. D. Alesin's article was discussed at a conference examining the results of the work of service inspection agencies with the participation of representatives from 30 plants and the GKL.

The conference in the main approved the desirability of changing the procedure in planning inspection work. Special attention should be paid to helping the plants to solve such important questions as production automation, etc. In this respect the activity of the laboratory should be aimed at fulfilling the main tasks set by the seven-year plan for the development of our national economy, and for the technical progress in our country.

At the same time the conference considers that the state inspection of instruments used in checking essential technological processes, in testing finished products, various equipments, installations and materials, as well as instruments used in acceptance and delivery testing carried out at plants and other organizations, should only be made if there are no service inspection agencies at the plants. If such an agency exists at the plant state checking by the Committee's agencies in the enumerated cases should not be carried out, the testing should be made by the factory or the central test laboratories, providing they are guided by instruction 12-58.

Extracts from the Proceedings of the Conference called by the Gor'skii GKL (State Inspection Laboratory) of Measuring Equipment

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 61, May, 1961

V. D. Alesin's article was discussed at the conference of the linear and angular section of the GKL technical council with the participation of 15 representatives of industrial establishments in the Gor'kii council of national economy. The conference considers that compulsory state inspection should be determined not by the type of the measures and measuring instruments, but by their application in the specific conditions of the plant.

The list of instruments and the dates for their state checking should be determined, in the opinion of the conference, by the GKL itself, and should include reference (primary) instruments, instruments which cannot be checked by the plant itself, and those on the special list of the Committee (weighing and commercial instruments, cash registers, etc.). The representatives of the Gor'kii council of national economy plants agreed that the general organization of the GKL activity recommended by V. D. Alesin reflects the present-day actual requirements presented by the industry to the laboratories. This requires an immediate reorganization of the whole activity of the GKLs.

In view of the important problems facing the GKLs the conference recommended the Committee's Measuring Instruments Administration to supplement the personnel of the GKLs by qualified workers capable of dealing comprehensively with the questions indicated in V. D. Alesin's article. The Administration should also find means of financing the GKLs in order to supplement systematically their equipment with new measuring instruments.

IMPROVING THE STATE AND OPERATION OF THE MEASURING EQUIPMENT

M. I. Shvartsman

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 61-62, May, 1961

The personnel of the Osh GKL (State Inspection Laboratory) branch for measuring equipment in close collaboration with representatives of industrial establishments of the region is conducting outstanding work for establishing uniform, accurate and correct use of measures and measuring instruments.

Having worked out a schedule for replacing obsolete measuring equipment by modern instruments they are systematically and persistently striving to apply it.

For instance, in the 3rd quarter of 1960 alone the branch helped to replace 49 obsolete instruments and those which were difficult to repair in the preliminary pressing, and the drying and sorting shops of the Karasuisk oil extraction plant and to equip the starting apparatus with new instruments which were previously lacking. This plant has compiled a schedule covering the whole of 1961 for exchanging obsolete by new equipment. The application of this schedule will provide a saving of at least 10,000 new rubles.

Similar measures have been taken in several other plants of the region, including the M. V. Frunze metal mining combine. However, the equipping of plants with modern measuring apparatus is often opposed by the supply organizations of the Kirgiz SSR Sovnarkhoz (Council of National Economy), which for 2-3 years has failed to implement requests for new measuring instruments.

In the 3rd quarter of 1960 the branch carried out a comprehensive heavy inspection of the measuring equipment at several plants, the results of this inspection were discussed at conferences attended by chief engineers and leading experts. These discussions were followed by instructions appointing persons responsible for the condition and opera-

tion of the measuring equipment in each shop or department and in the plant as a whole. A one-day seminar on the maintenance and operation of measuring instruments was organized for the persons made responsible for the equipment.

The branch adopted measures for improving the condition of the measuring equipment in commercial establishments. For this purpose a heavy inspection was organized in which 50-60% of the instruments were actually checked. The data obtained in this inspection were summarized and brought to the notice of the leaders of commercial organizations and the Ministry of Trade of the Republic.

At the same time the desirability of establishing service inspection was impressed on the leaders of commercial establishments. As a result of this work the condition of the measuring equipment in commercial enterprises was somewhat improved and service inspection is being organized.

In 1960 the condition of the measuring equipment and the quality of production at the city enterprises was discussed at a meeting of the Osh city Soviet executive committee. It was decided to instruct the heads of enterprises to improve the quality of production, and the inspection of the measuring equipment, as well as to take the necessary steps for gradual replacement of obsolete instruments by new ones.

In conjunction with the city Soviet and the quality inspection of the Kirgiz SSR Ministry of Trade the branch checked up on the observance of standards and technical specifications in the baker, wine and vodka plant, meat canning combine, furniture factory and a plant making nonalcoholic drinks. The result of this work was also discussed at the meeting of the city Soviet.

In the 3rd quarter of 1960 the branch carefully checked measuring equipment of the stocking deparment in a cotton-ginning mill. A seminar was organized for goods inspectors in charge of checking raw cotton, at which they were instructed on servicing the measuring equipment used in testing cotton.

In addition to the above organizational and technical measures the branch fulfilled its planned task in collecting the required amount in payments for testing and general inspection.

Yet the branch encounters certain difficulties in its work. For instance, the filling of exceedingly detailed forms in financial and operational accountancy takes up much time which could be more profitably used in other work.

Moreover, two measuring instrument branches are operating on the territory of the Osh region. Neither branch is subordinate to the other and, therefore, it is impossible to coordinate or concentrate the inspection work, and this hinders the organization of conferences of the service inspection personnel, of workers in commercial enterprises for discussing improvements in the quality of products, the adoption of standards, and the carrying out of the regional Soviet executive committee's decisions, etc.

The personnel of the branch hopes that the Kirghiz GKL will decide the question of the subordination of one branch to the other and will take the necessary steps to reduce the form-filling in financial and operating accountacy.

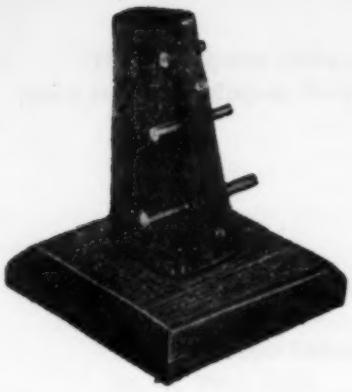
PYRAMID FOR SETTING MICROMETERS

A. P. Vasil'ev

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 62, May, 1961

It is known that for setting micrometers to their zero position it is necessary to fix them in a special stand and then place the calibrating gauge between the measuring surfaces of themicrometers.

In the absence of proper supports on the benches the operators have to turn with one hand the micrometer ratchet and with the other hold the micrometer and insert the calibrating gauge between its measuring surfaces. Such a method of setting micrometers damages the calibrating gauges.



Block gauges are often used in test laboratories for setting the zero position of micrometers. This wastes the time of workers and inspectors and leads to premature wear of block gauges.

In order to eliminate all these drawbacks we suggest the use of a simple device, consisting of a wooden block in the shape of a pyramid with the calibrating gauges firmly fixed in it (see Figure). Gauges with the smallest error should be selected for this purpose.

This device is being successfully used at several engineering plants.

INFORMATION

SEMINAR ON METROLOGY AND MEASUREMENT TECHNIQUES

V. V. Pen'kov

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 64, May, 1961

The TsBTI (Central Bureau of Technical Information) of the Tula Sovnarkhoz (Council of National Economy) together with the Tula branch council of the NTO (Scientific and Technical Department) of engineering organized with the halp of the Interchangeability Bureau (BV) of the metal-working industry, the Tula GKL (State Inspection Laboratory) and the Tula Mechanical Institute a seminar on metrology and measurement techniques, which was held in December, 1960, in Tula.

Some 100 representatives of test laboratories and technical departments of various organizations and establishments of the Tula Sovnarkhoz participated in the work of the seminar.

At the seminar 15 papers were read by representatives of the BV, the Tula GKL, the NII (Scientific Research Institutes) and the KB (Design bureaus).

G. A. Polivoda, head of the Tula GKL, gave in his report on the "Importance of technical supervision of measurement equipment and examination of regulation 12-58," a number of specific examples showing the importance of the correct organization of the inspection of measures and measuring instruments according to regulation 12-58.

The papers of the BV representatives A. G. Draudin on the "Modern state of technical measurements and their basic problems," and on the "Modern means of dimension control in engineering," and of N. N. Markov on the "Modern means and methods of checking gear wheels," dealt with existing types, means and methods of checking and indicated their further development and improvement.

N. N. Markov in his paper entitled "Choice and allocation of measuring and control equipment," dealt with the techniques of selecting and allocating the checking equipment and methods by their accuracy, as well as by their economic features depending on the nature of the dispersion in the article dimensions and the required accuracy of their manufacture.

B. S. Banin in his paper on the "Correct organizational and technical cooperation of test laboratories with technical departments is the guarantee of success of the measurement and metrological technology," dealt with problems facing the test laboratories in addition to the maintenance of uniform measures and correct and accurate measurements, and analyzed how these problems should be solved.

The procedure of checking measures and measuring instruments and certain peculiarities of their testing were dealt with in the papers read by P. S. Platonova entitled "Checking block and angle gauges and the equipment used for it."

Certain practical problems of measurement were dealt with in the papers S. A. Chicherova on "Measurements of external and internal cones," of K. P. Churyukina on "Organization of measurement and control of surface finishes and their measurement in accessible places by means of the casting method," and of A. P. Povarov on "Measurement and control of flats."

In addition to the above papers were also read on the organization of set gauges inspection (A. P. Burenin), the mechanization of inspection under conditions of large-scale mass production (V. V. Buyanov) and under conditions of a rotor conveyor line (E. N. Frolovich).

The participants of the seminar noted the opportuneness of the questions raised and indicated the necessity of examining other problems in the activity of test laboratories.

In their resolution the participants of the seminar decided to use in their work the data presented to the session, and elected an organizing committee for preparing a conference on metrology and measurement techniques in 1961.

The participants of the seminar visited several plants in the town, where they inspected the work of test laboratories and the equipment for mechanizing production inspection.

NEW EXHIBITIONS

Translated from Izmeritnel'naya Tekhnika, No. 5,
pp. 64, May, 1961

A British Trade Fair will be held in the Moscow "Sokol'niki" park of rest and culture from May 18 to June 4, 1961. This Fair will be the largest foreign exhibition ever held in the USSR both with respect to the number of exhibition ever held in the USSR both with respect to the number of exhibitors and exhibits. It is intended to have at the Fair a "Scientific Instruments" section at which various instruments and apparatus used for measurements, calculations and control will be exhibited, including the most modern electronic instruments and apparatus.

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On August 15, 1961 a large French exhibition will be opened at the "Sokol'niki" park of rest and culture in Moscow. The exhibition will present French industrial products, including those of the instrument-making industry, as well as material representing the cultural and scientific life in France.

FROM THE JOURNALS

FEINGERATE TECHNIK

No. 2, 1961

G. Glezer. Measuring torque in spiral springs used in measuring instruments and tools and in watch mechanisms.

G. Meister. The importance of measurement techniques in production from the point of view of automation.

No. 3, 1961

R. Obst. New optical instruments of the Zeiss company shown at the Leipzing spring fair in 1961.

K. Burchardt. Instrument for measuring the pitch of guide screws.

Attachment to the polarization microscope "Poladun IV" of the optical firm Ratenauer.

Application by the Zeiss company of the Mitrofanov method for group machining of components.

G. Weinhold. Measuring by means of balls cylindrical gear wheels with external and internal meshing.

E. Gultch. Basic principles ofmeasurements by means of precision instruments.

ARCHIV FUR TECHNISCHES MESSEN

No. 297, October, 1960

Brief review of the exhibits shown at the international exhibition of automation and measurement techniques "Interkama" held in Dusseldorf in 1960.

D. Rolf. Magnetic flowmeter. Description of its design, principles of operation, methods of calibration and the sphere of its application.

A. Ebinger. Measurement of high-value resistances. Description of themethods for measuring insulation resistance directly, by evaluating current, by means of a bridge or a discharging capacitor.

W. Wisner. Precision capacity measurements, part I. The direct capacity and the capacity between the plates and the screen. Basic principles of the measuring methods. Reference capacitors and bridge measuring circuits.

P. Holdinghauzen. Digital methods of measuring voltage. Digital measuring methods and components of digital measuring circuits.

G. Teller. Requirements for unified measuring and control systems.

G. Ketler. Reference high-precision voltage transformer. Methods of determining transformer errors, configuration of the core and windings, errors of new reference transformers with toroidal cores.

No. 298, November, 1960

G. Weinek. Technical measurements at metallurgical plants. Basic principles and circuits for measuring pressure, flow, temperature and for gas analysis are given.

Transistorized capacitance measuring bridges. Measuring range of 0.1 $\mu\mu$f to 100 μf with an error of $\pm 1\%$.

I. S. A. JOURNAL

No. 1, 1961

International symposium on temperature measurements from absolute zero to 10000°K (Columbia, Ohio, USA, March 27-31, 1961).

D. Goldstein and others. Oil flowmeter with a device for compensating viscosity variations of the measured liquid. It measures flows of less than 38 liter/hr.

Ionization absolute pressure manometer with a cold cathode using ultraviolet rays for ionizing gas. Measuring range from 10^{-9} to 10^{-10} mm Hg.

No. 2, 1961

New type potentiometer in which the slide wire is replaced by a strain gauge transducer.

The necessity to eliminate the lagging of measurement technology as compared with the general development of technology in the USA.

Measurement standards in science and industry.

V. Wildheck. National Bureau of Standards, a center for establishing and preserving American standards. Basic standards in the possession of the NBS are described.

S. Richardson. Test circuits and the system of checking measuring instruments in the National Bureau of Standards.

B. Axeman. Determining the profitableness of checking measuring instruments.

F. Harris and R. Katkovskii. Improved methods for measuring capacitance. Circuits are given for measuring the capacitance of two-terminal and three-terminal capacitors. Utilization of a calculated air capacitor as a standard capacitance. Application of transformer bridge circuits.

Training of metrologists in the USA. Opening of a new scientific instructional center for measurements at the Washington University. The functions of the center and the subjects which will be taught in the 1961 scholastic year are given.

Bibliography of the US publication on the subjects of measuring standards and testing methods.

R. Mandt. Simple method for calibrating level regulators. Recommended ambient conditions for test laboratories.

VDI ZEITSCHRIFT

Vol. 102, No. 30, 1960

A. Leote. Spheres of application of measurement techniques. Brief content of a paper read at the International Congress and Exhibition on measurement techniques and automation "Interkama", in Dusseldorf in 1960.

J. Koals. Application of statistical methods in designing control systems. Theroretical considerations of the advantages in using statistical methods for designing control systems.

L. Marz. Trends in the development of measurement techniques and control systems in thermal technology and production. History of the development of various types of regulators, instruments and control boards.

E. Gereke. Concepts of pulses. Basic propositions in measurement techniques and regulation.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

AN SSSR	*Academy of Sciences, USSR*
FIAN	*Physics Institute, Academy of Sciences USSR*
GITI	*State Scientific and Technical Press*
GITTL	*State Press for Technical and Theoretical Literature*
GOI	*State Optical Institute*
GONTI	*State United Scientific and Technical Press*
Gosénergoizdat	*State Power Press*
Gosfizkhimizdat	*State Physical Chemistry Press*
Goskhimizdat	*State Chemistry Press*
GOST	*All-Union State Standard*
Gostekhizdat	*State Technical Press*
GTTI	*State Technical and Theoretical Press*
IAT	*Institute of Automation and Remote Control*
IF KhI	*Institute of Physical Chemistry Research*
IFP	*Institute of Physical Problems*
IL	*Foreign Literature Press*
IPF	*Institute of Applied Physics*
IPM	*Institute of Applied Mathematics*
IREA	*Institute of Chemical Reagents*
ISN (Izd. Sov. Nauk)	*Soviet Science Press*
IYap	*Institute of Nuclear Studies*
Izd	*Press (publishing house)*
LÉTI	*Leningrad Electrotechnical Institute*
LFTI	*Leningrad Institute of Physics and Technology*
LIM	*Leningrad Institute of Metals*
LITMiO	*Leningrad Institute of Precision Instruments and Optics*
Mashgiz	*State Scientific-Technical Press for Machine Construction Literature*
MGU	*Moscow State University*
Metallurgizdat	*Metallurgy Press*
MOPI	*Moscow Regional Pedagogical Institute*
NIAFIZ	*Scientific Research Association for Physics*
NIFI	*Scientific Research Institute of Physics*
NIIMM	*Scientific Research Institute of Mathematics and Mechanics*
NIKFI	*Scientific Institute of Motion Picture Photography*
NKTM	*People's Commissariat of the Heavy Machinery Industry*
Obrongiz	*State Press of the Defense Industry*
OIYaI	*Joint Institute of Nuclear Studies*
ONTI	*United Scientific and Technical Press*
OTI	*Division of Technical Information*
OTN	*Division of Technical Science*
RIAN	*Radium Institute, Academy of Sciences of the USSR*
SPB	*All-Union Special Planning Office*
Stroiizdat	*Construction Press*
URALFTI	*Ural Institute of Physics and Technology*
TsNIITMASh	*Central Scientific-Research Institute of Technology and Machinery*
VNIIM	*All-Union Scientific Research Institute of Metrology*

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

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Russian original published by the Ministry of Light Metals, USSR. The articles in this journal relate to instrumentation for analytical chemistry and to physical and mechanical methods of materials research and testing. 1958-1961 issues available.

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